AIRS Forward Model Validation and Status

AIRS Science Team Meeting: Nov/Dec 2004

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UMBC Physics Department and JCET

Estimated *AIRS* RTA accuracy via ARM-TWP and ECMWF validation studies.

RTA accuracy now on order of instrument accuracy (except for high-altitude water and Non-LTE). Maybe another factor of 2-3x improvements to reach instrument relative accuracy.

RTA accuracy in upper troposphere, stratosphere hard to validate.

AIRS sees variability in CO_2, CO, SO_2, CH_4, N_20. No N_2O or SO_2 in standard RTA.

Look more carefully at AIRS spectral calibration for climate studies.

Do cloud-cleared data show same bias characteristics? (Wednesday)

Preliminary work with SARTA-Scattering shows reasonable abilities to simulate dust and cirrus. Particle habit, dust indices of refraction, aerosol altitude, as always, present challenges. (Thursday)

Climate with AIRS

- Is the DAAC record for weather or climate? I assume climate.

- Climate requirements allow higher standard deviations, but lower mean errors.

- Need L1b, RTA to track instrument calibration changes and slow atmospheric changes (CO_2)

- AIRS has additional climate information:
    - IR dust forcing
    - IR cirrus (thin)
    - Minor gases (CO, CH_4, CO_2, SO_2, maybe N_2O)
    - Surface emissivity

- Level 1b may be most important climate record
    - How inform users of subtle instrument changes in L1b?
        - Frequency calibration
        - Fringes

RTA Liens (over mission)

1. (Lev 1b:) Frequency calibration (Level 1b or RTA): +-0.1K max
2. (Lev 1b:) Fringes (Level 1b or RTA): +-0.3K max
3. (Lev 1b:) Scan asymmetry: 0.1K max, surface channels only
4. (Lev 2:) Cloud-cleared radiance accuracy (Wednesday)
5. Spectroscopy: 0.2K+? (upper trop/strat not validated), 6K (non-LTE)
6. Parameterization accuracy: generally < 0.05K
7. Regression profiles sufficiently diverse? ??
8. Variable gases: N_2O: 0.7K, CO_2: 0.8K, CH_4: ?, SO_2 and CO even more
9. Use of RTA above cloud deck: ??
10. Reflected thermal for low emissivity land scenes: 0.5K or more
11. Dust: 5K+ (makes it through cloud clearing) (Thursday)
12. Cirrus: N/A (Thursday?)
13. Emissivity variations with SST: 0.3K

Note: Bias stability may be < 0.01K per year!

Would like RTA stability to approach this number??

Being worked

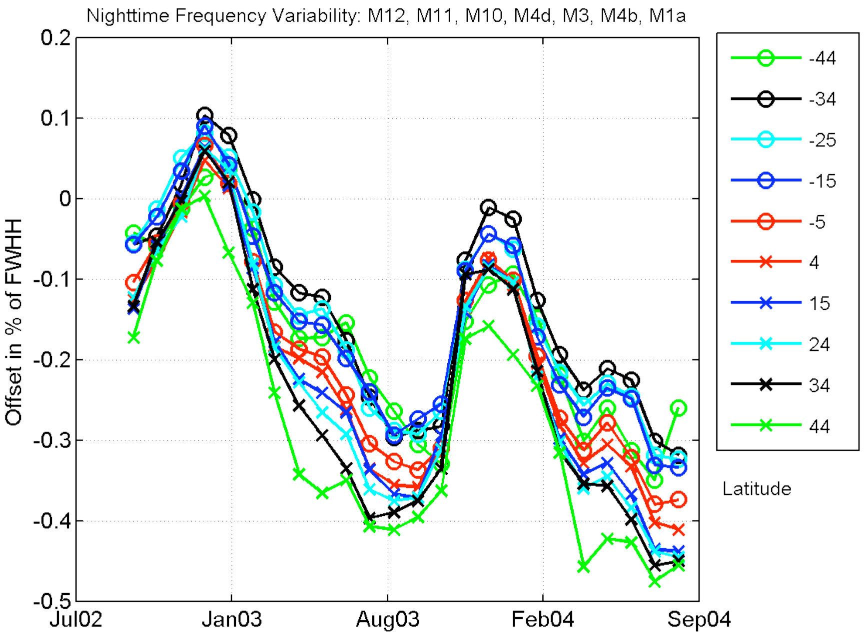
Worked in past

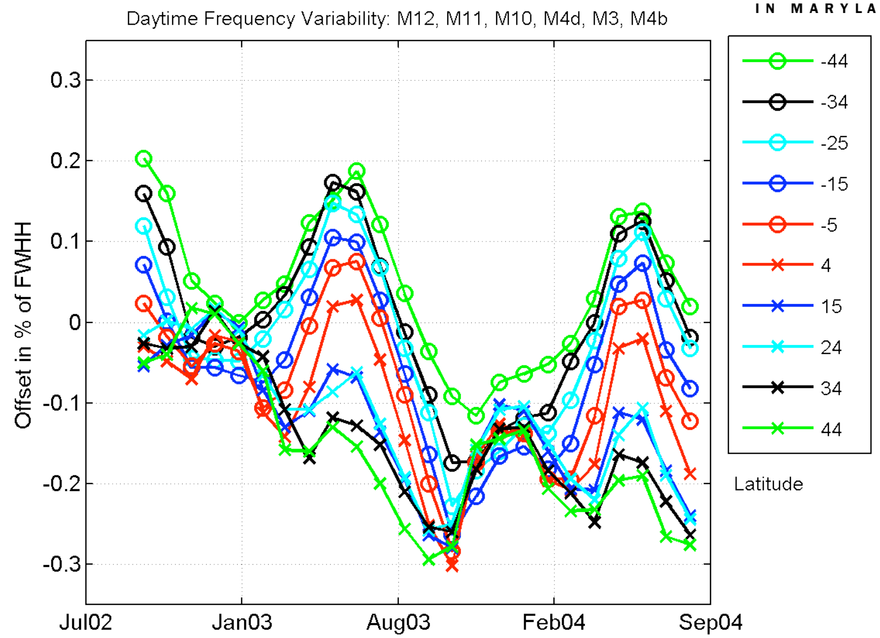
Difficult problem

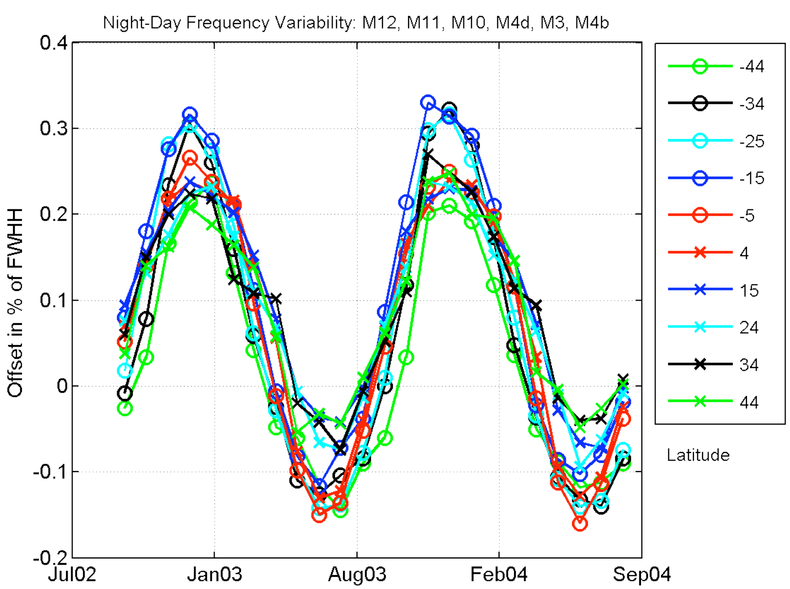
Frequency Calibration

- Frequency calibration has 3 major terms:
  - Short term solar forcing: ascending/descending each with time variation that maps into latitude
  - Seasonal variation in above short term solar forcing, correlates with solar beta angle
  - Longer term drift
- We have performed a 2-year frequency calibration
  - Used UMBC's uniform clear L1b subset
  - Use sharp features in radiance due to CO_2 and H_2O. (Avoid 4.3 μm CO_2 band head.)
  - Compared B(T)'s computed from ECMWF to observed B(T)'s, shift frequency scale, via grating model, to minimize differences.
  - Bin monthly averages by latitude and day/night.
  - 7 arrays used to obtain average $\Delta\nu$.
  - M12 appears to be offset by 1 μm.
- Matlab routine developed to correct frequency calibration errors
  - Uses computed radiances to determine local $dB(T)/d\nu$ derivatives
  - Could be implemented as part of the RTA (Inputs: latitude, day/night, either month or solar beta angle, extrapolation of slow longer term drift).

AIRS Frequency Calibration





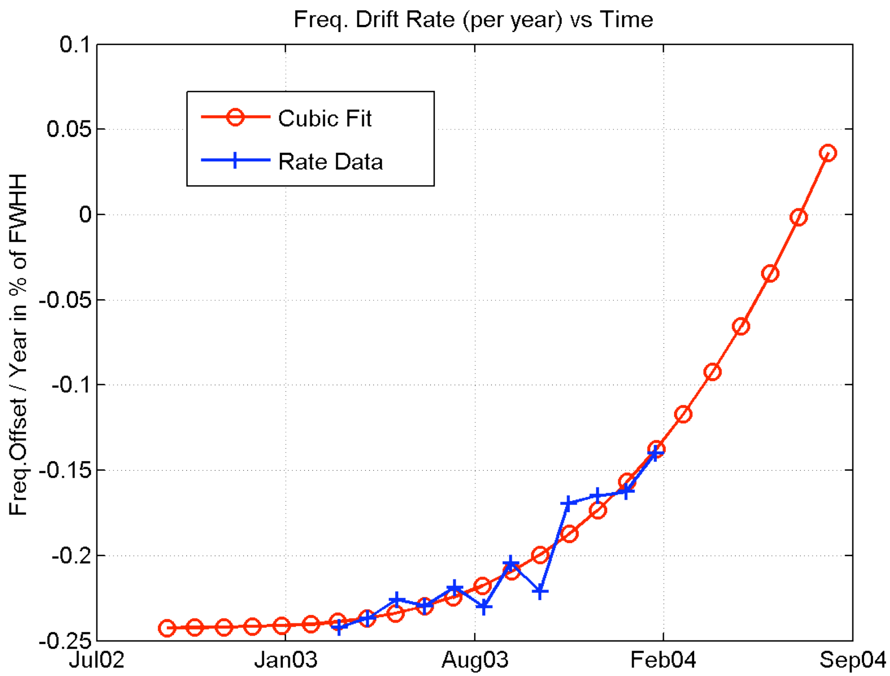


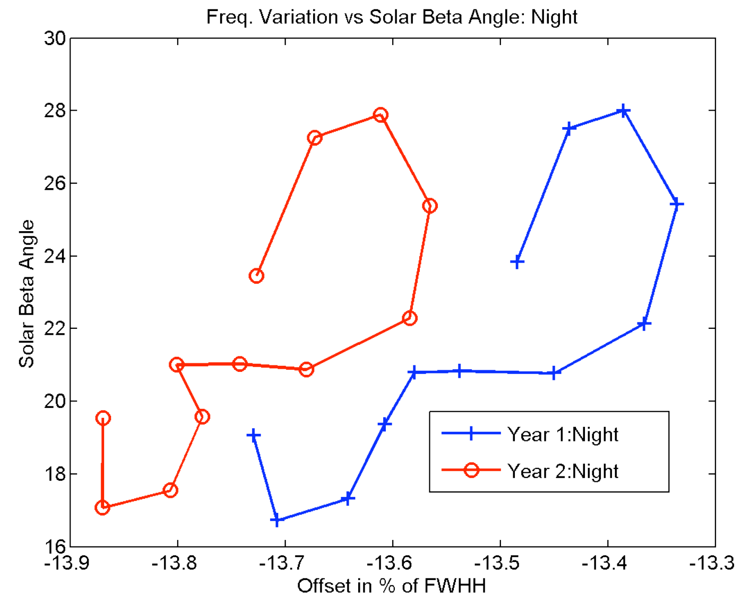
Nov. 03 shift: 0.11% of width

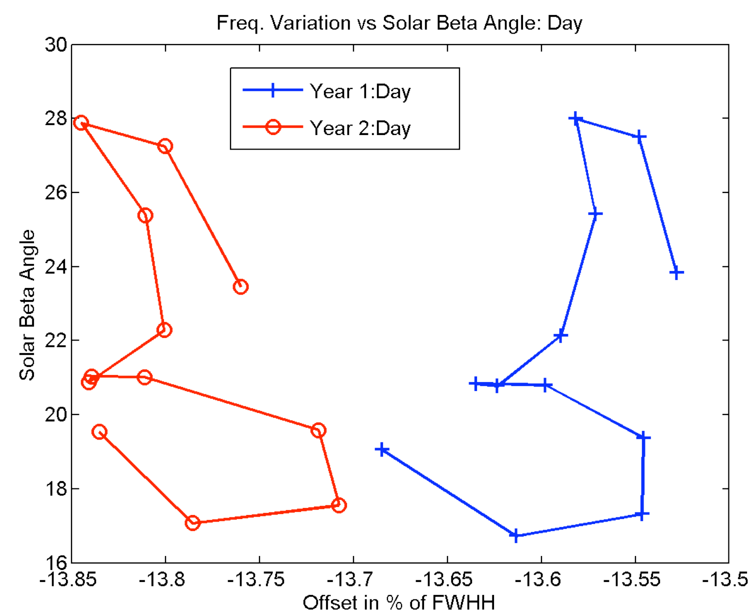
Day – Night $\Delta\nu$ shows almost pure sinusoid

Although M12 is offset by 1% of a width from other arrays, it varies similarly in time

Frequency Calibration



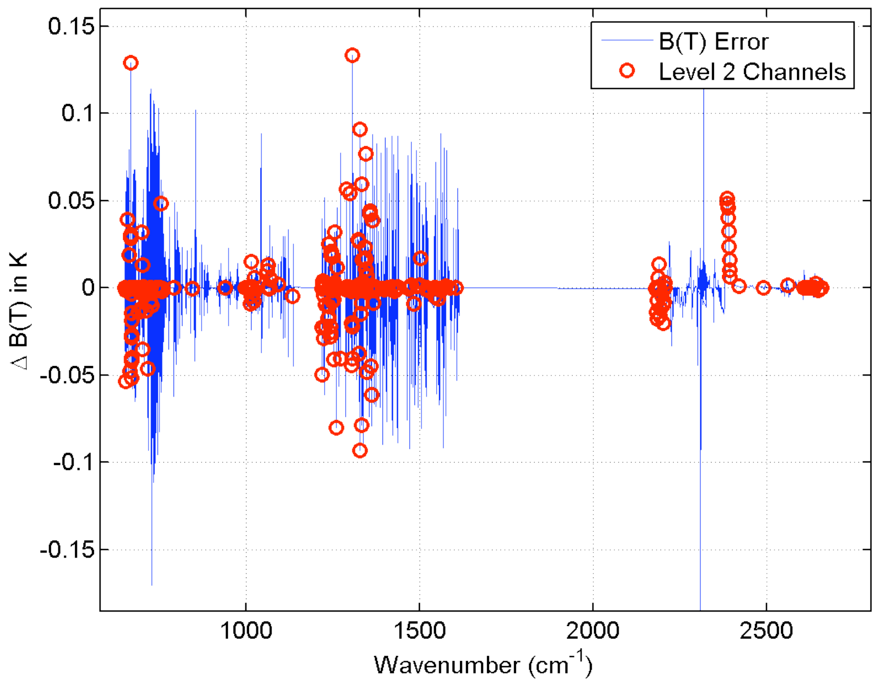


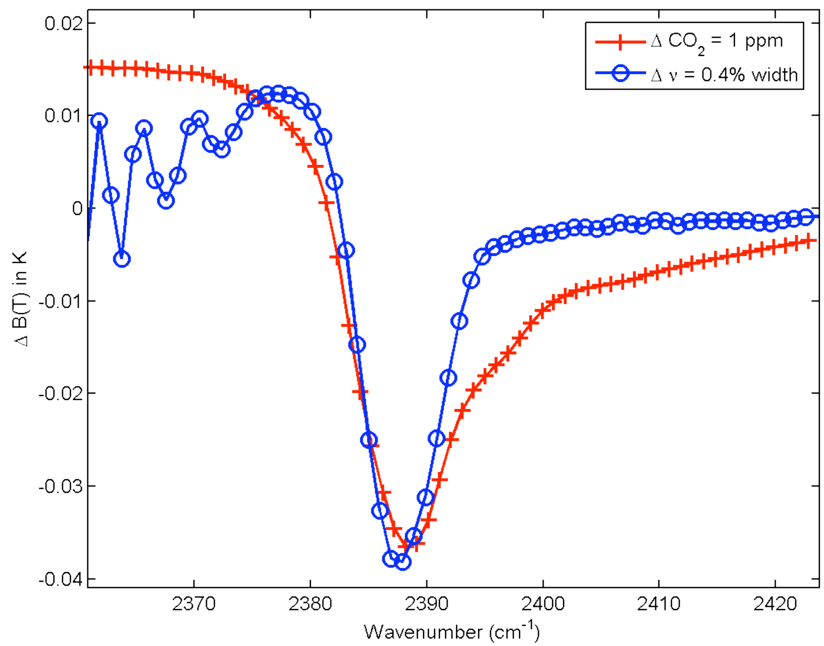


Total Freq. Variation:

0.3% orbital + 0.1% Nov. 03 + 0.8% slow drift ~ > 1% drift over life of mission.

Frequency Calibration



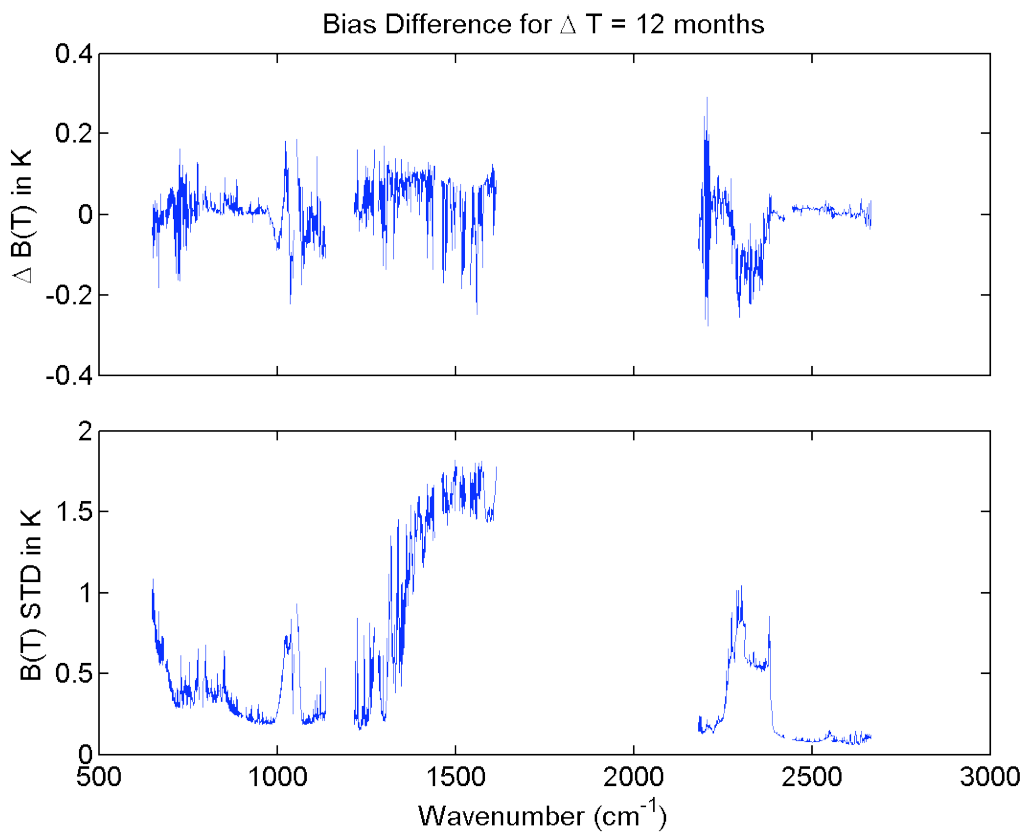


Note: Nov. 03 frequency shift of 0.11% width is easy to see in monthly mean biases relative to ECMWF for sensitive channels.

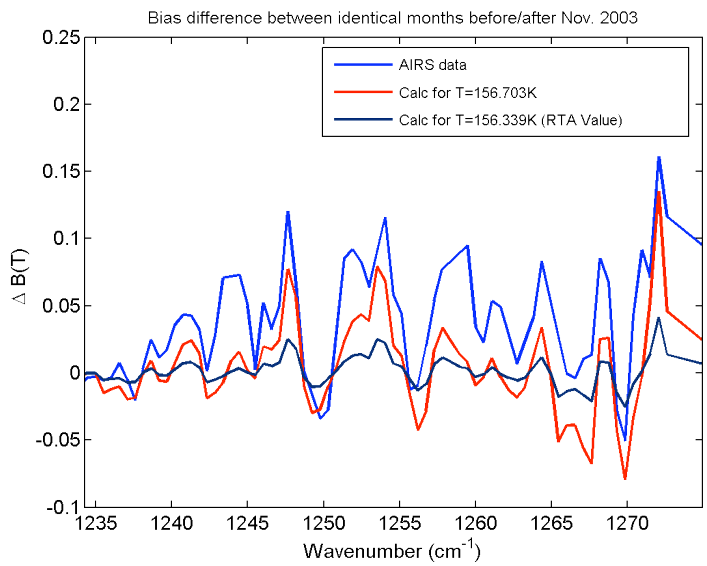
Difference between a frequency shift and variable CO_2 almost impossible to separate. Note that the 4.3 μm channels are very good for CO_2 due to low water sensitivity.

Fringes

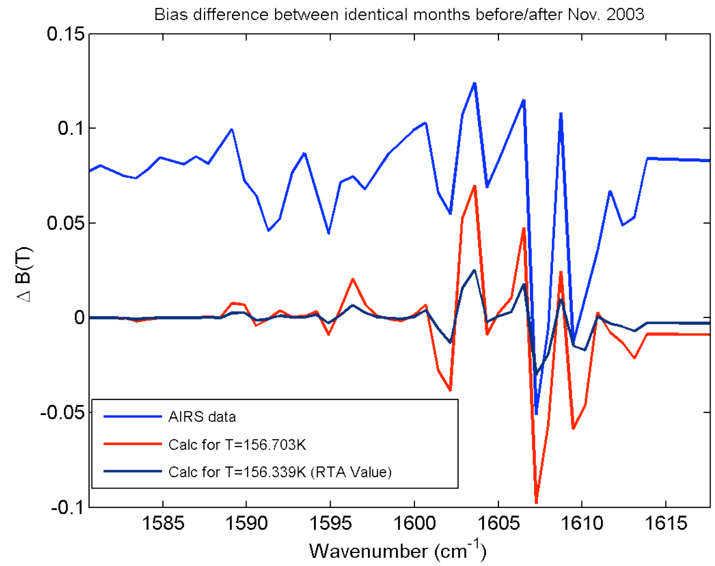
- Fringes moved due to Nov 03 shutdown
  - –Goal was to keep frequencies unshifted
  - –Resulted in different temperature for filter producing fringes
- Somehow, we got the wrong filter temperature when producing the post Nov. 03 RTA
- Moreover, the decision was made to have only one RTA for reprocessing, using the supposed post-Nov. 03 fringe positions
- So fringes are incorrect for all AIRS data



Fringes



Bias difference between identical months before/after Nov. 2003
AIRS data
Calc for T=156.703K
Calc for T=156.339K (RTA Value)
Δ B(T)
Wavenumber (cm^{-1})



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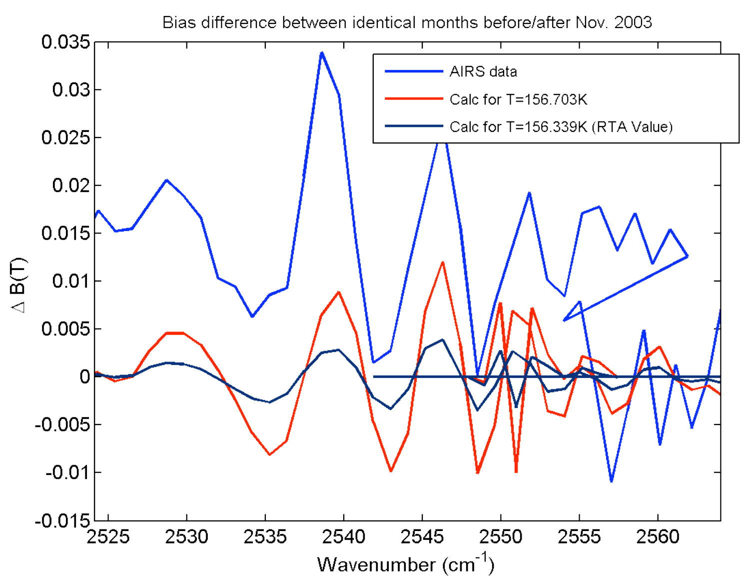

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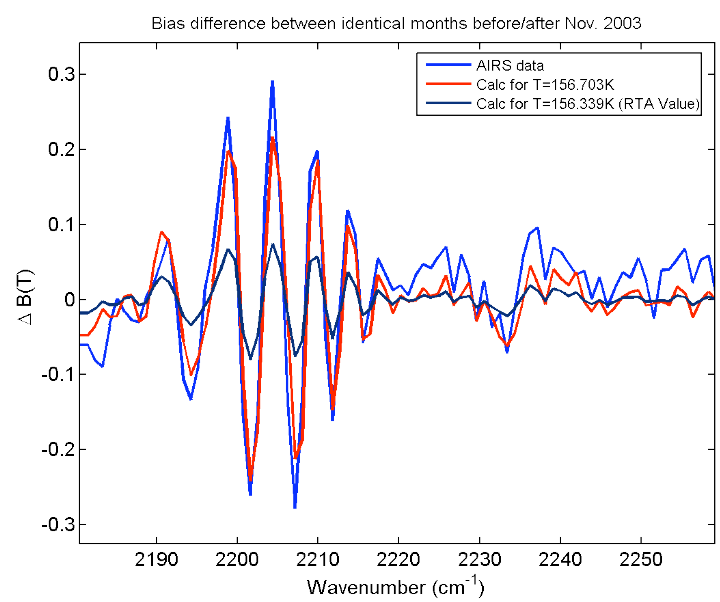

Bias difference between identical months before/after Nov. 2003
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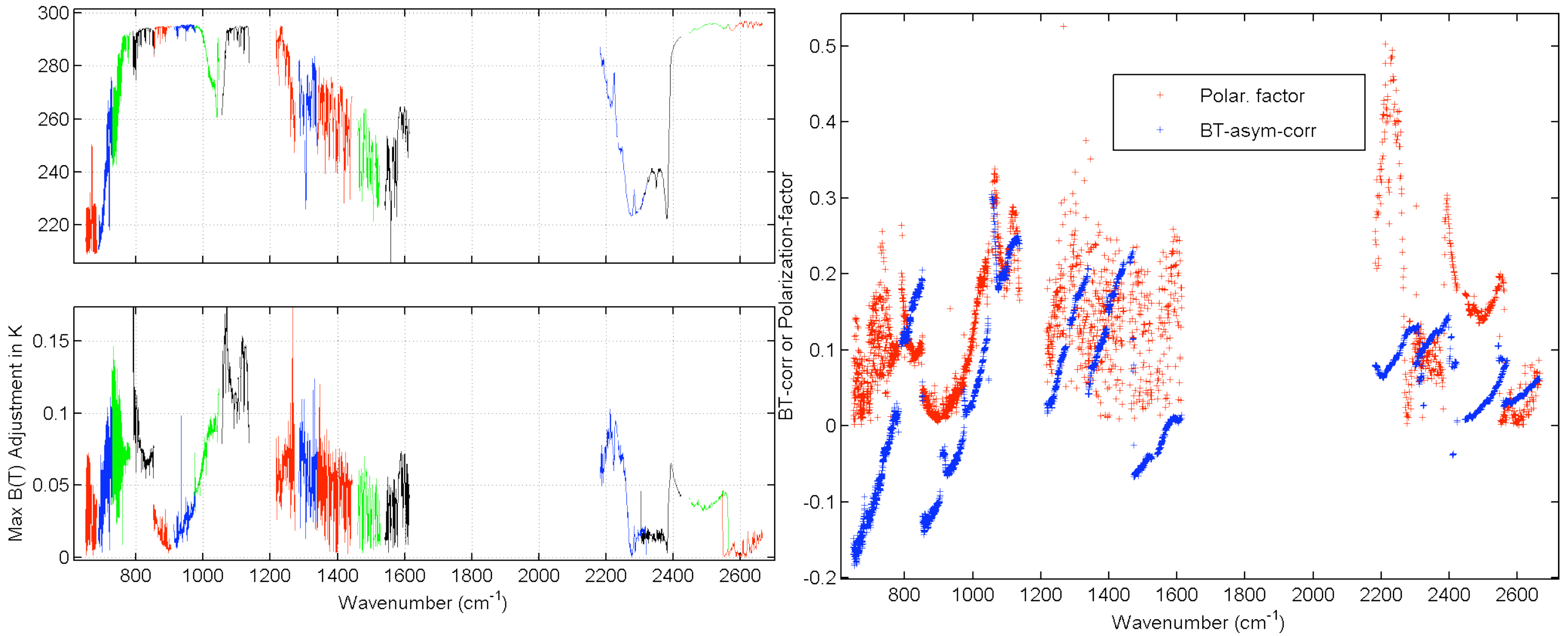
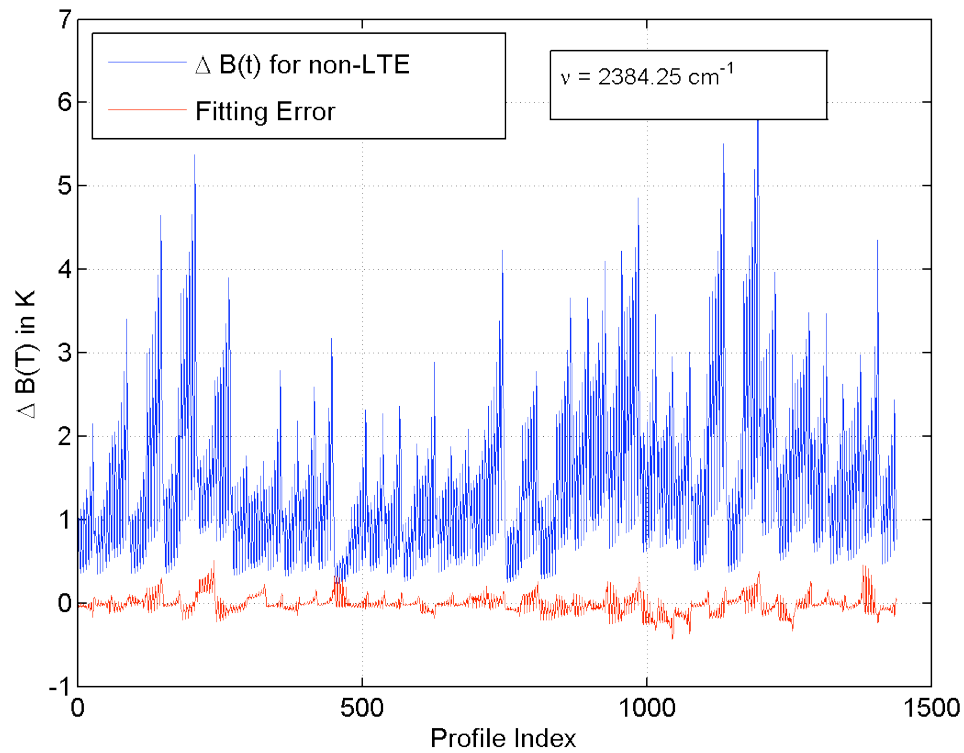
Wavenumber (cm^{-1})

Max Scan Bias Asymmetries



Non-LTE

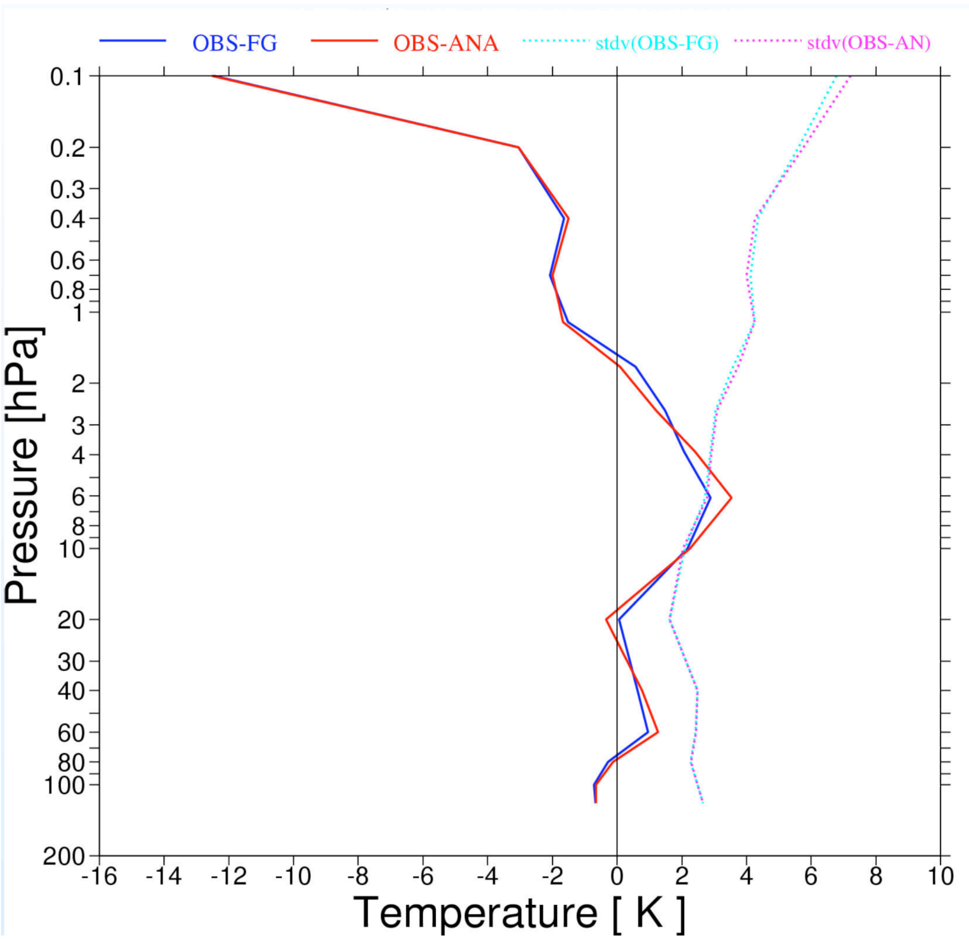
- Some work on fast non-LTE model.
- Fast parameterization looks good, fundamental theory being tested
- First principles calculations are relatively good, but need non-LTE vib/rot temperatures, not a simple calculation
- Non-LTE small for ~2380 cm^{-1} region: corrections should be easy
- Various possibilities:
  - –Use 15 micron channels in regression for 4 micron non-LTE along with solar angle
  - –Use strong non-LTE in 2330 cm^{-1} region to predict non-LTE in ~2380 cm^{-1} region (use ECMWF to estimate amount of non-LTE near 2330 cm^{-1}).
- Does anyone care?



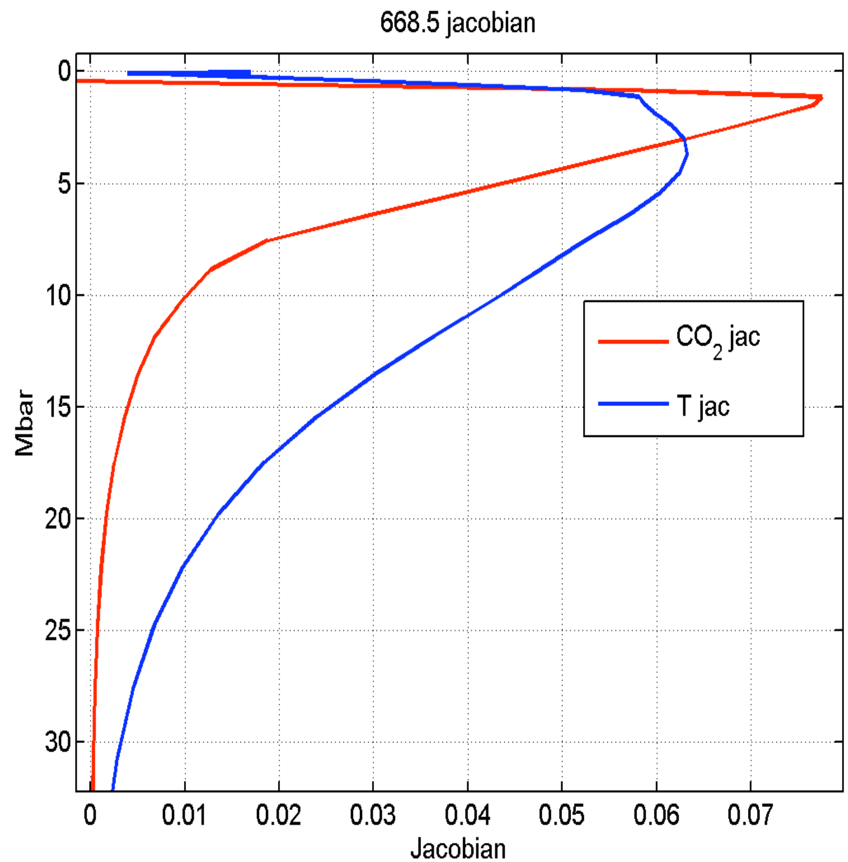
Variable Gases

- CH_4 and N_2O can vary significantly, including in the stratosphere where AIRS channels have sensitivity. CO_2 can vary slightly as well.
- I have observed many variations in CH_4, N_2O, and CO_2 channel biases (vs ECMWF) with latitude. These biases generally vary with the channels stratospheric sensitivity.
- Sensitivity studies using MIPAS constituent retrievals for CH_4 and N_2O show some significant AIRS sensitivties.
- Are highest altitude channel biases dominated by ECMWF (esp. for CO_2)?
- Biases change character as go to lower peaking channels
  - Due to variable CH_4, N_2O, CO_2, often in stratosphere?
  - CO_2 from 791.7 and 2390 cm^{-1} show excellent agreement with CMDL, including almost perfect variation with season at 50 degrees latitude.
- Much work needs to be done. Hope to utilize MIPAS monthly mean profiles for validation.
- These effects could pollute latitudinal dependence of AIRS products.

MIPAS for High Altitude RTA Validation?



MIPAS - ECMWF



Hopefully can get global monthly mean profiles from MIPAS (Oxford) for T, CH_4, N_2O

Stratospheric Variability

Due to long-time scale of trop to strat exchange

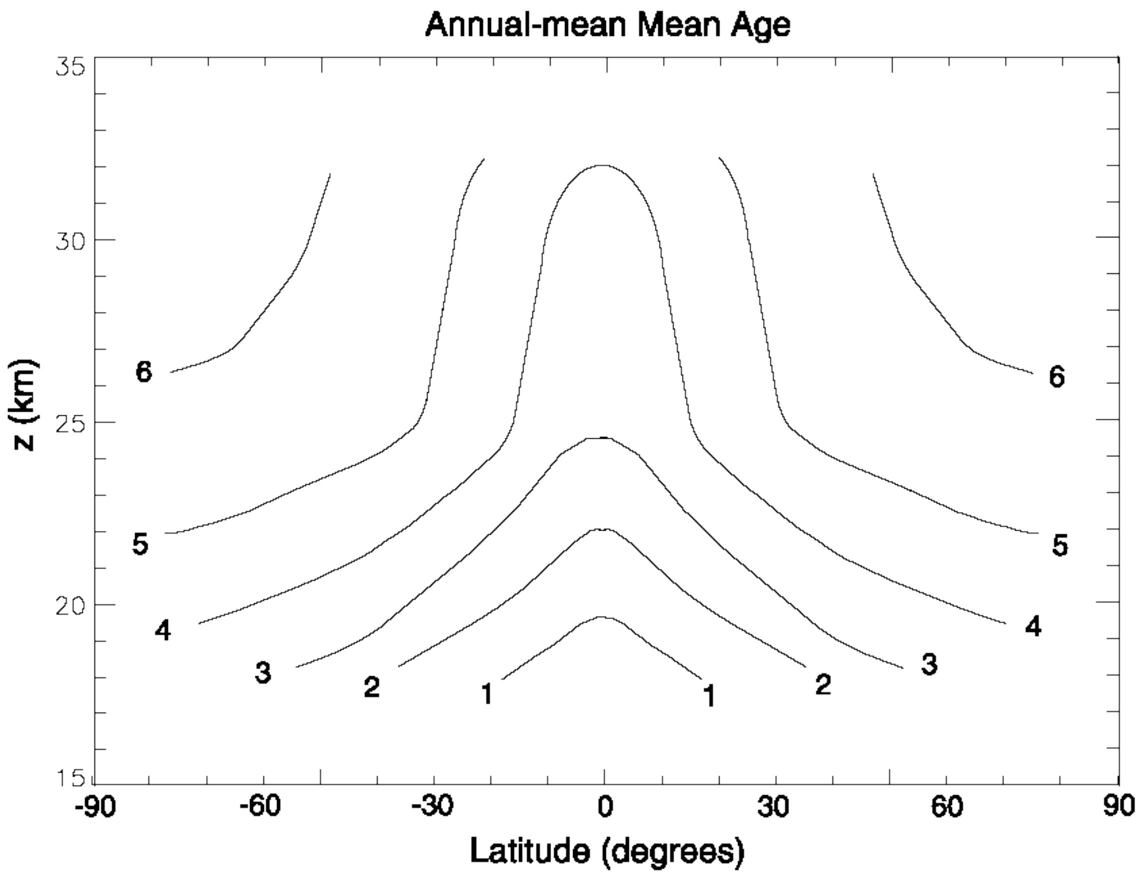
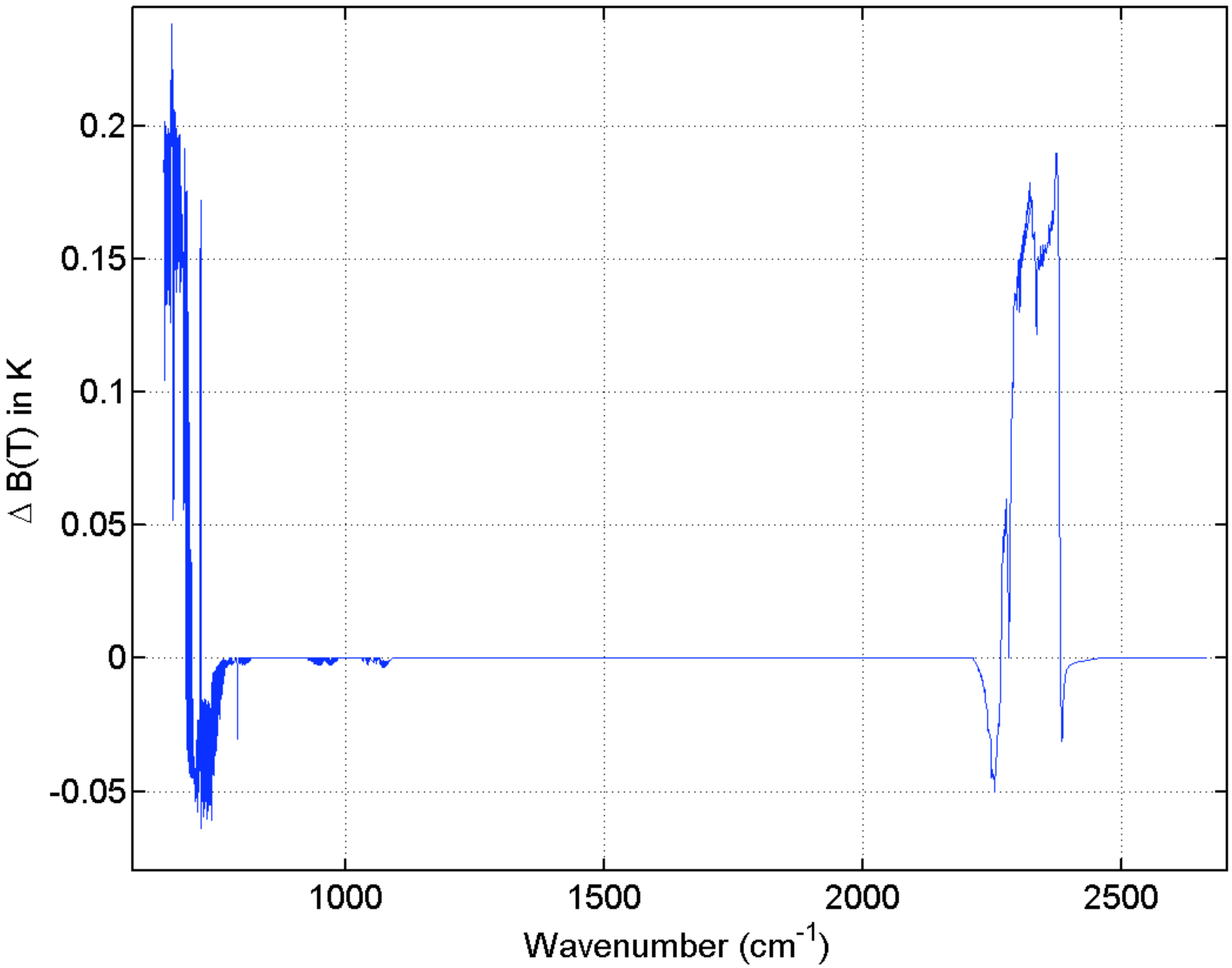


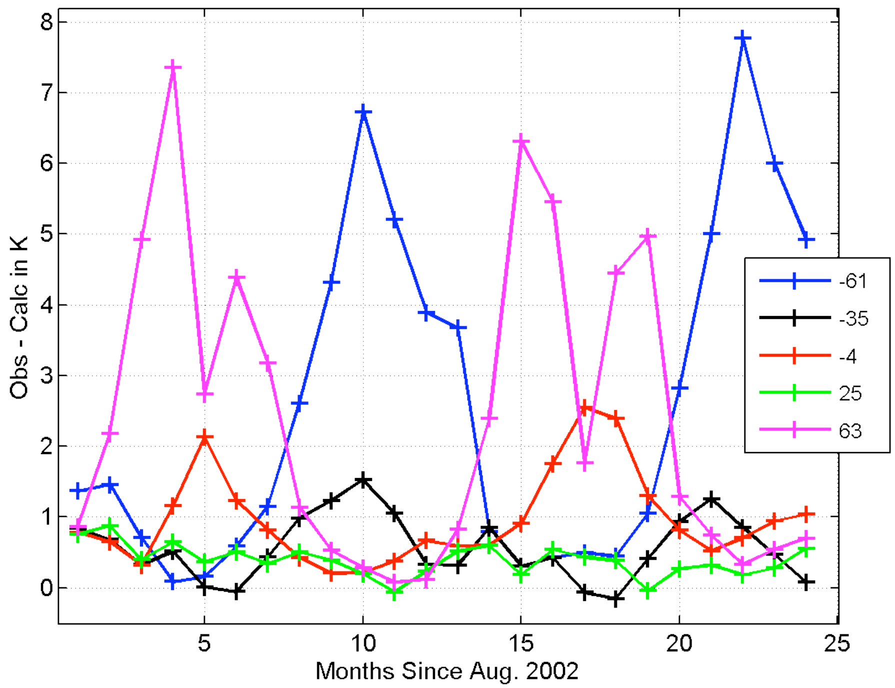
Figure 7. Schematic diagram of the altitude-latitude distribution of the annually averaged zonal mean of mean age based on vertical profiles from observations listed in Table 1 and ER-2 measurements around 20 km (e.g., Figure 6a). As it is based almost exclusively on Northern Hemisphere data, the schematic is hemispherically symmetric.

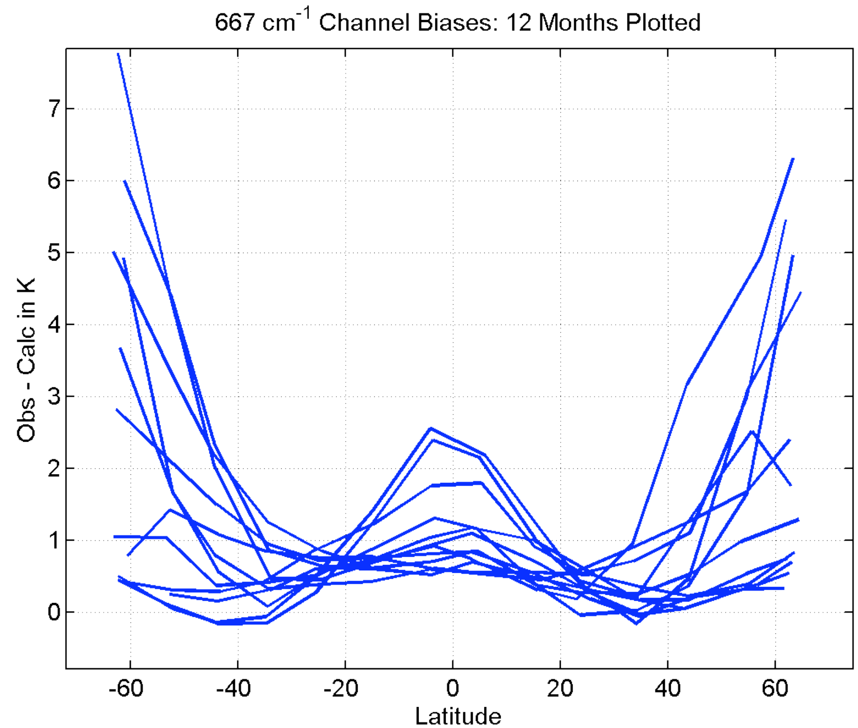
Rough Estimate of Stratospheric CO_2 Sensitivity

CO_2 varied in stratosphere using
nominal ER-2 measurements



Observed 667 cm^{-1} Biases versus ECMWF





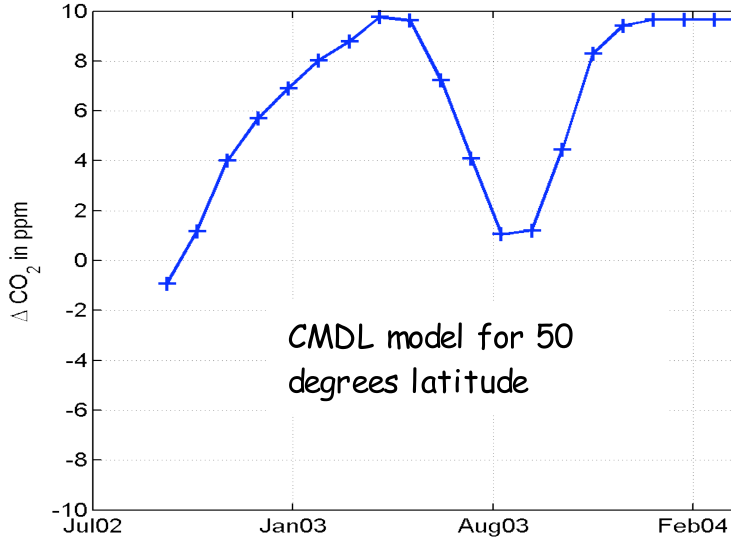
- Biases much larger than expected for stratospheric CO_2 variability, esp at poles
- Phase reversal between poles with time. 25 deg N very stable bias
- Unsure if biases are too large (2K) relative to MIPAS, need more details on latitude range of MIPAS biases relative to ECMWF
- Any suggestions?

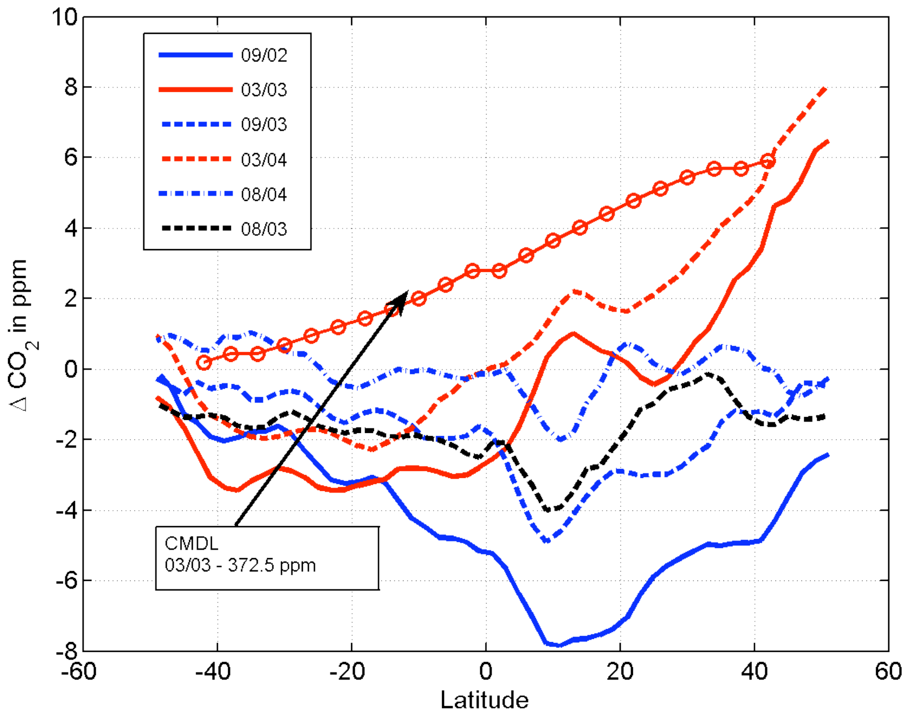
Smoothed CO_2

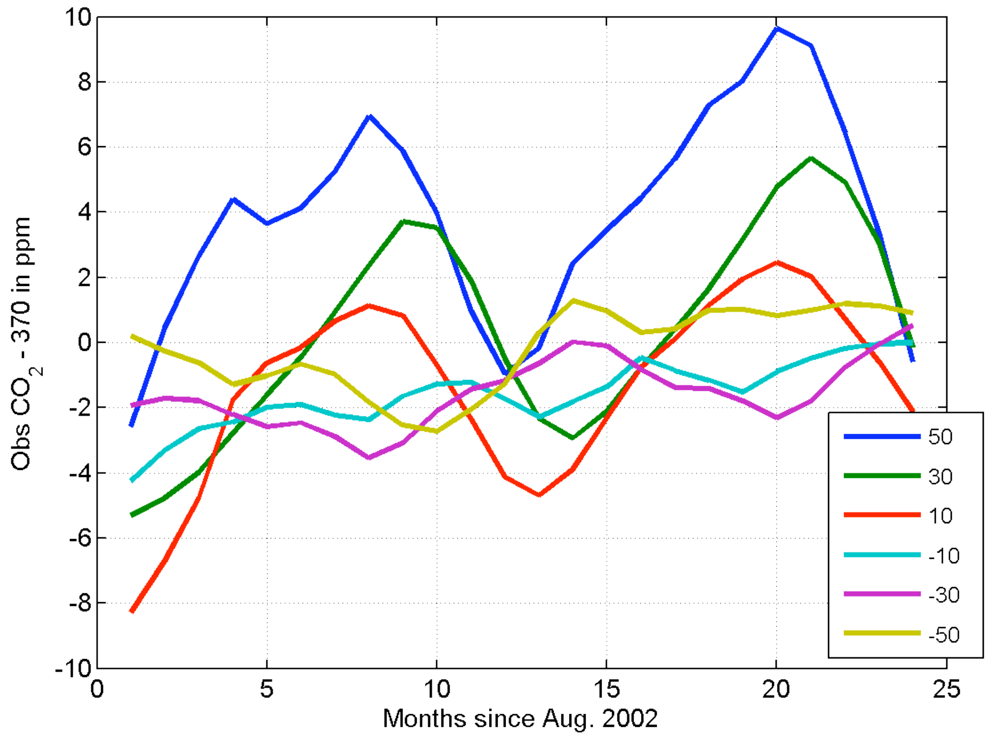
Data reproduces basic form of CMDL models

Need a single overall calibration, but within ~2-3 ppm initially

Is fine structure real?







Globally Averaged Result

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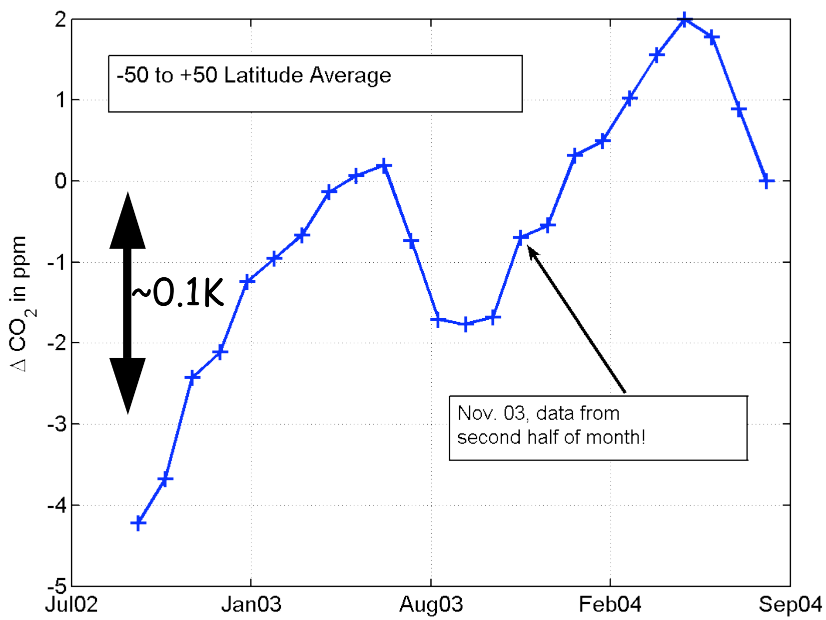

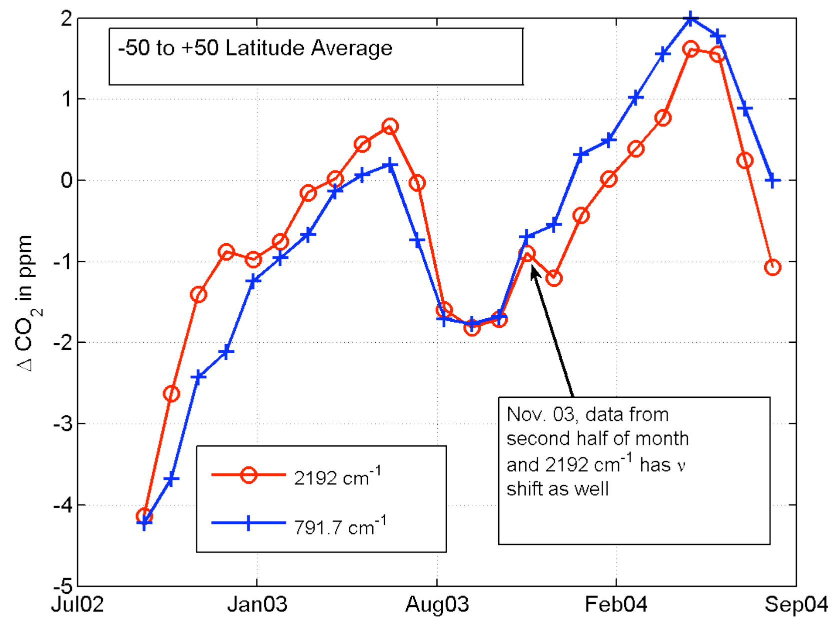

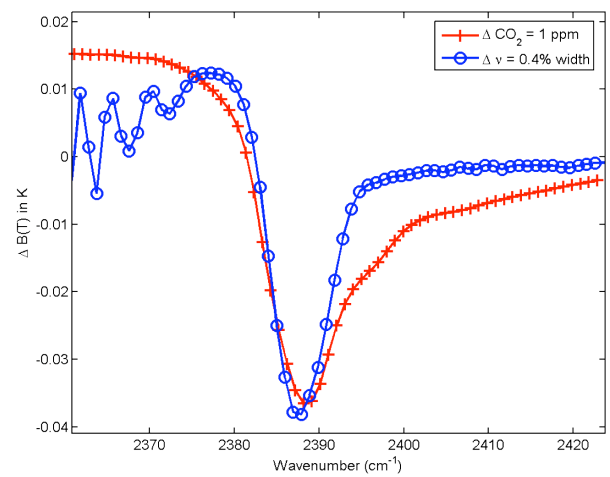

N_2O Variability

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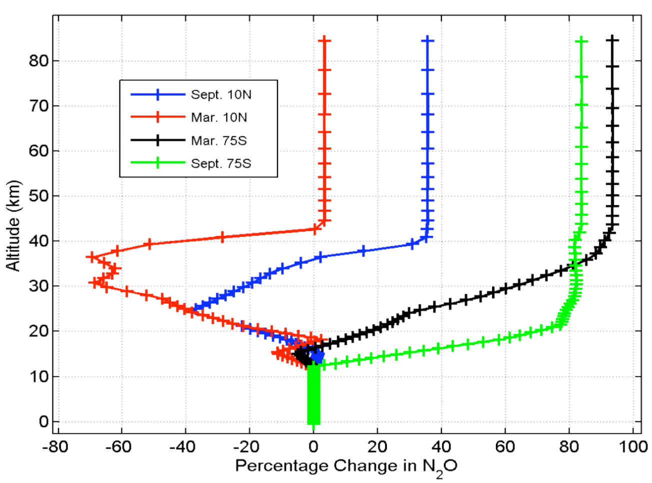
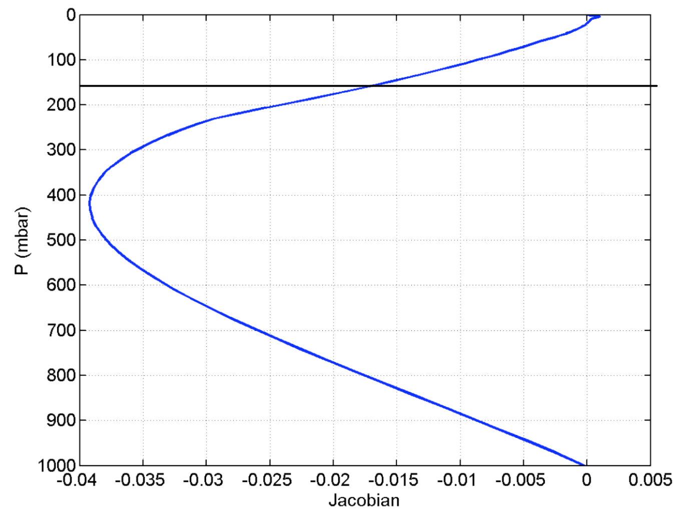
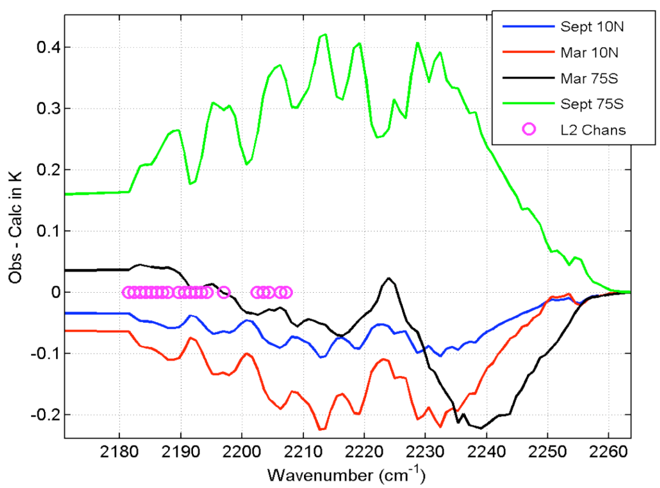
Nominal MIPAS Variability



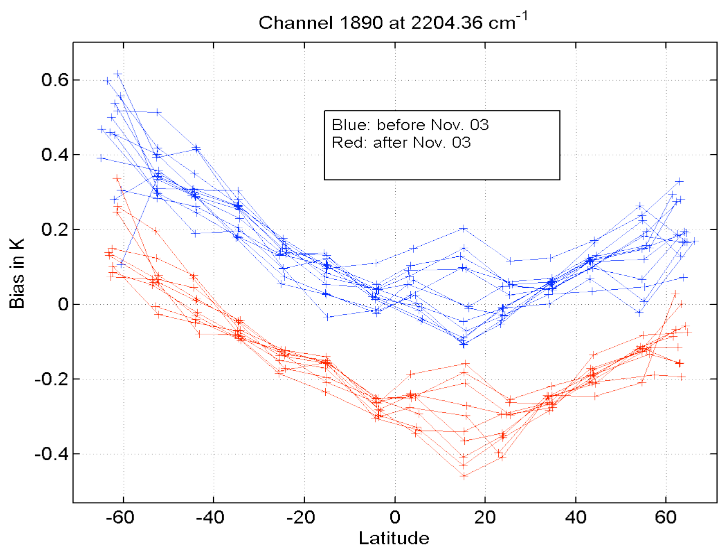
N_2O Jacobian for 2204 cm^{-1}



Computed Bias from Above Profiles

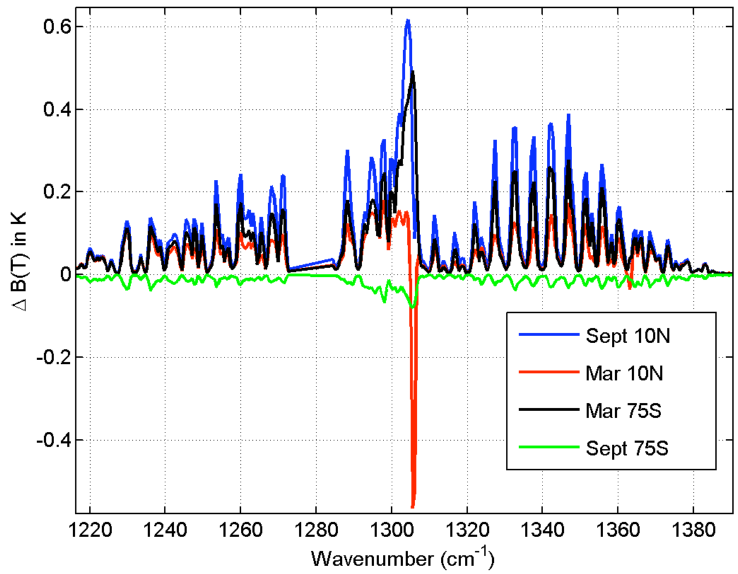


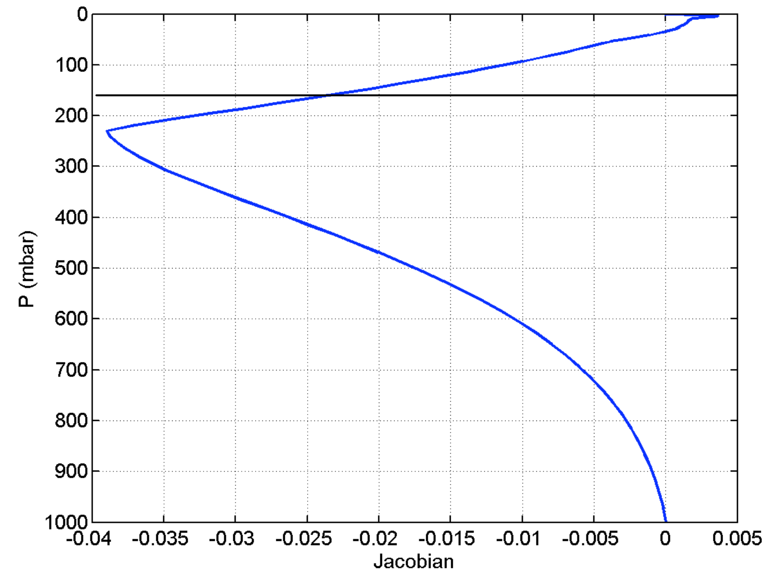
Observed Biases vs ECMWF

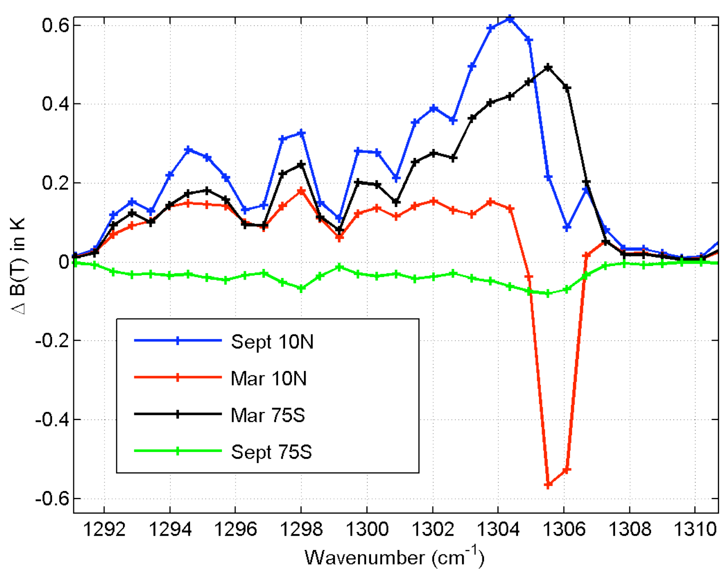


- Need to let N_2O vary in RTA?
- Sounding channels impacted by variable N_2O?
- Fringing effects long-term signal

CH_4 Stratospheric Variability (from MIPAS)



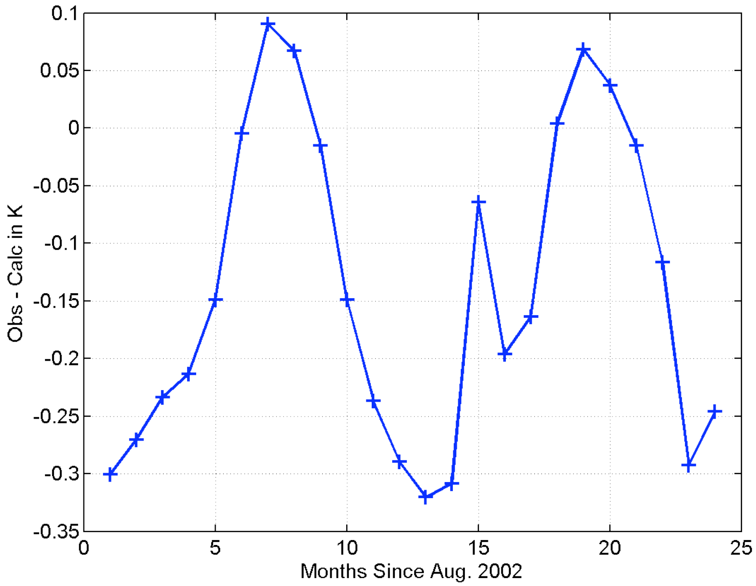


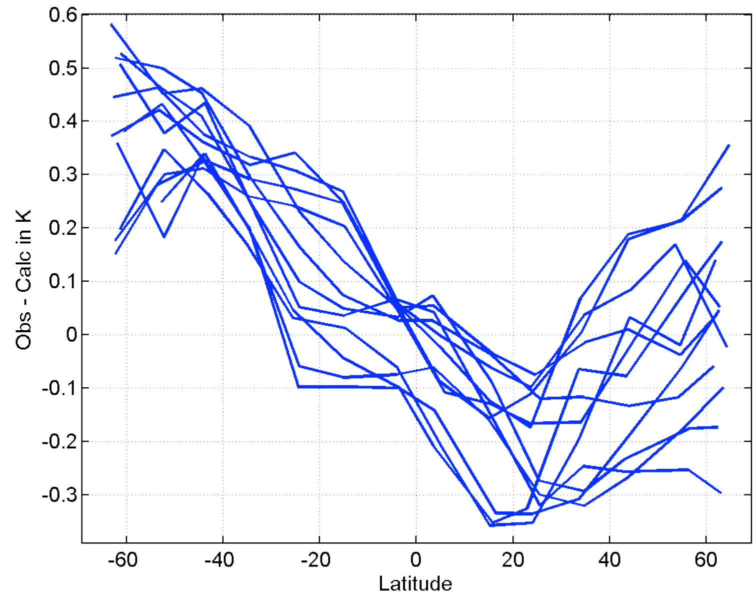


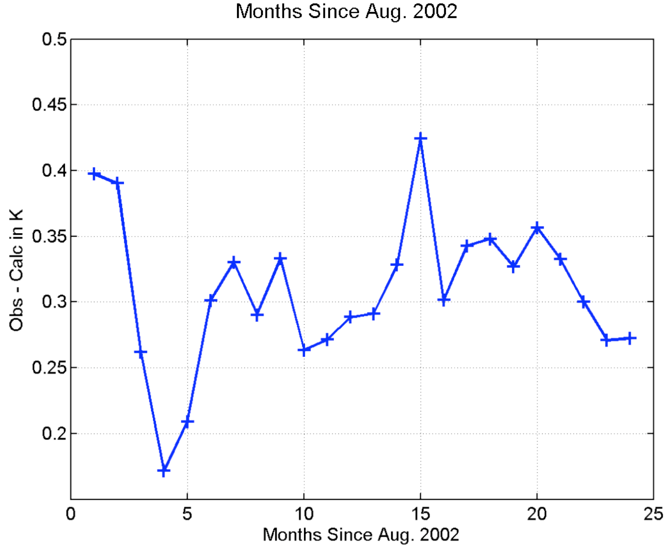
Observed Biases versus ECMWF in CH_4 Channels

CH_4 channel at 1304 cm^{-1}

Bias for 34 deg. N.







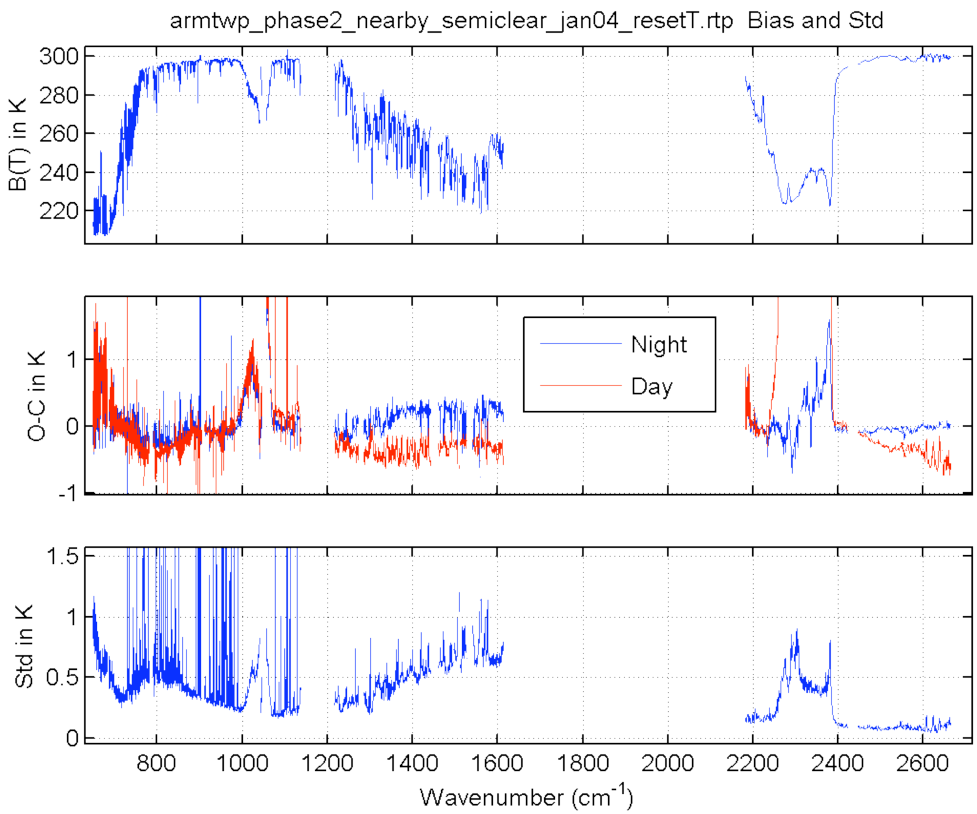
717 cm^{-1} channel bias for 34 deg. N. This channel's CO_2 Jacobian is very similar to the 1304 cm^{-1} channel CH_4 Jacobian.

ARM Validation

New results: Multiple phases helps with error analysis, priority for special issue

RS-90 sondes

Sonde calibration continuing – no Milosevich corrections used here



Clear determination from H. Aumann global SST studies. Probably lets through ~0.3K cloud signal, on average.

Fit for SST (minimizes clouds)

RTA from ARM-TWP 2002/2003

Used "global" clear-flag

~5% FOVs survived clear test

30-50 mm H_2O, = 7-11K depression at 800 cm^{-1}

ECMWF for T above sondes

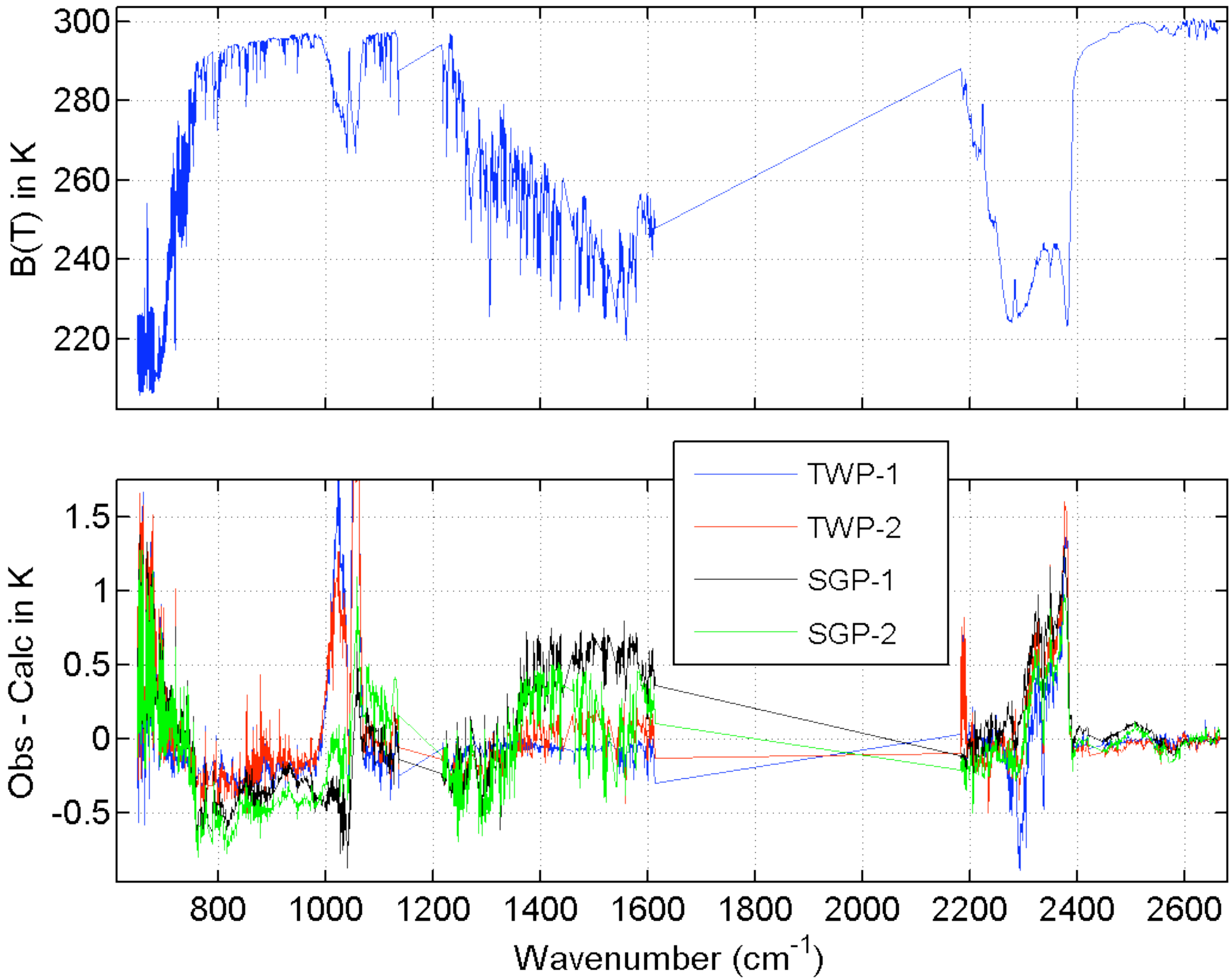
Most clear from Fall 2003

Brand new data, so preliminary, but probably best estimate of RTA error bounds.

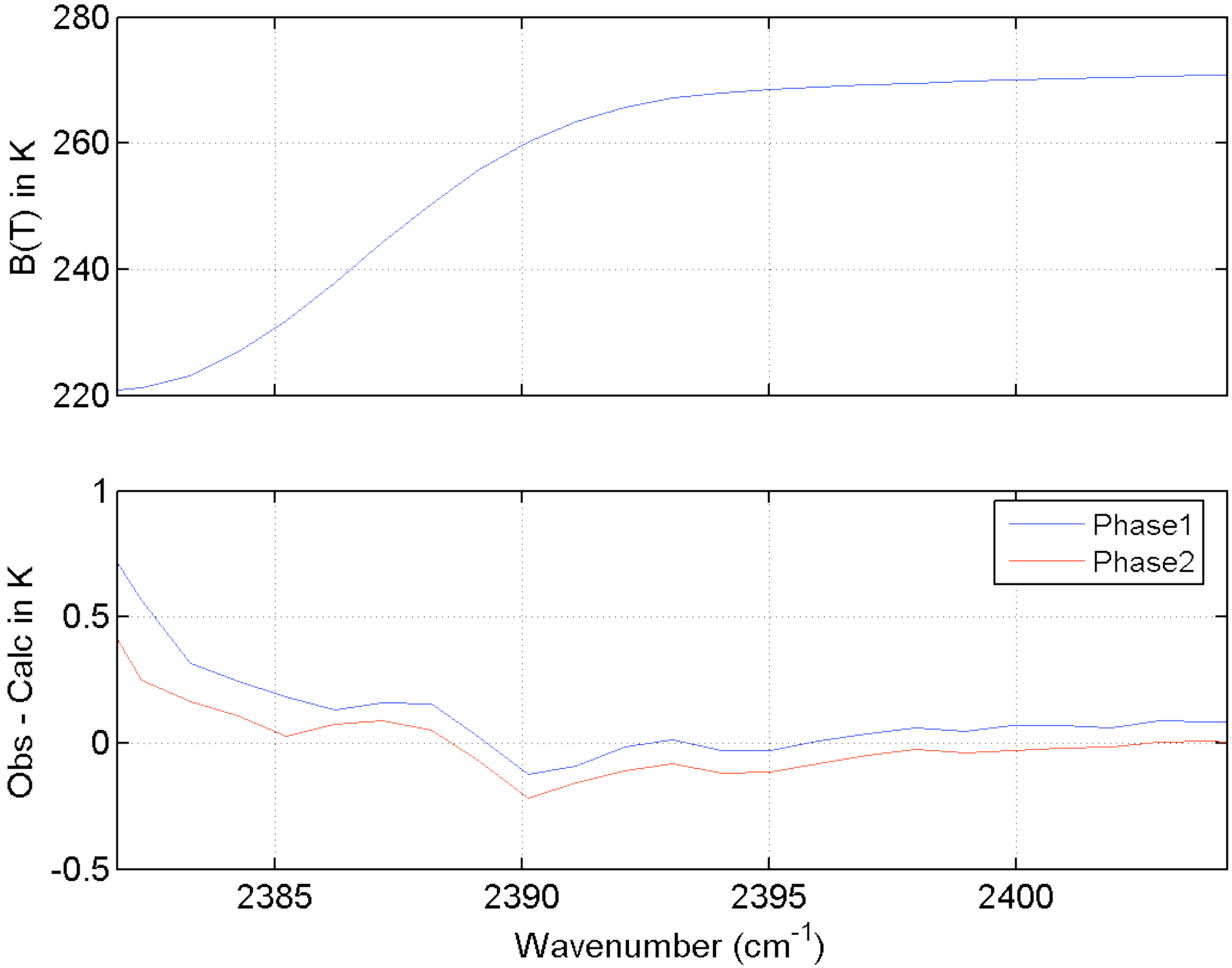
800-1000 cm^{-1} Errors = ~ 2% water

1400 – 1600 cm^{-1} Errors = ~3% water

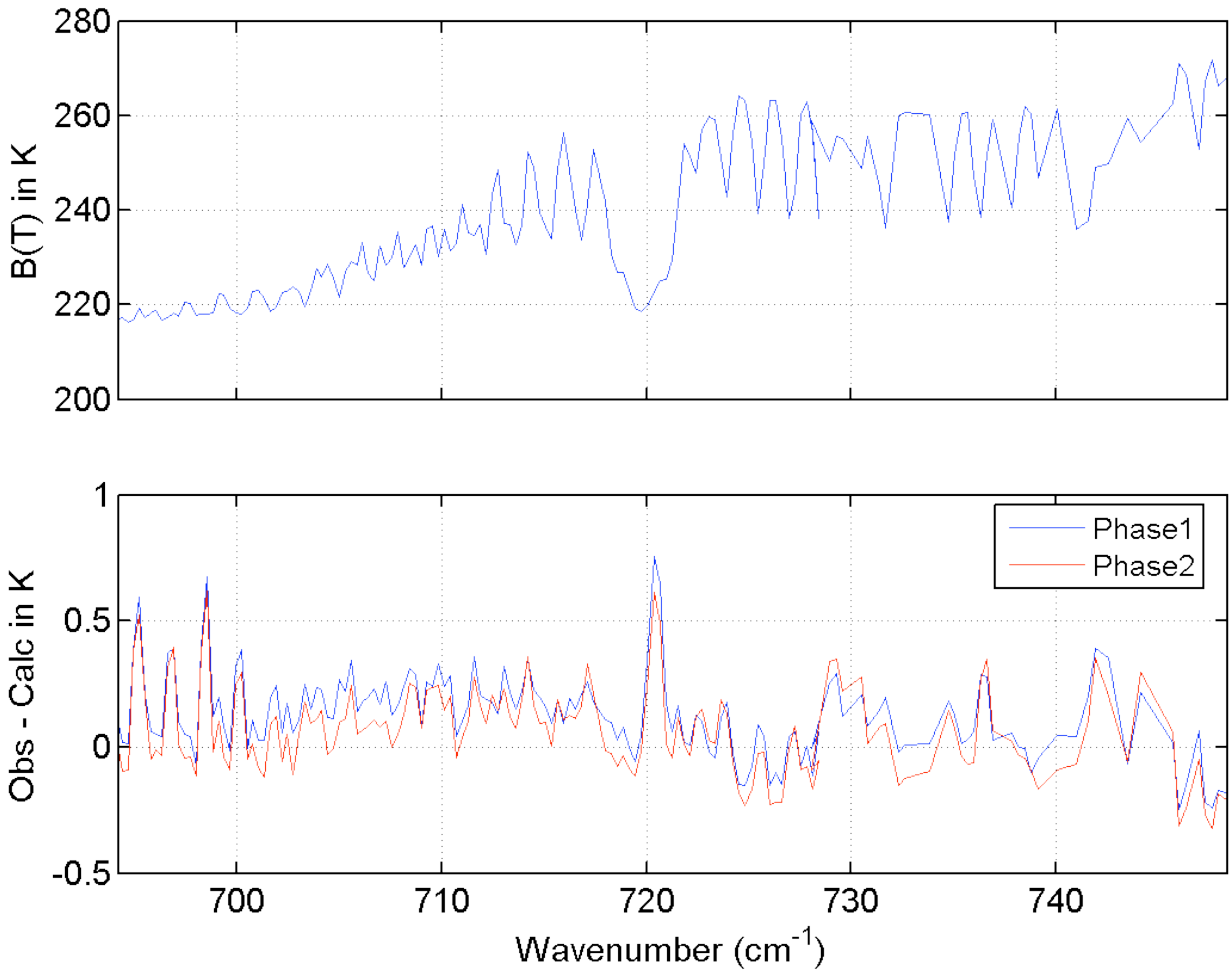
ARM: 2 of 3 Phases Ready



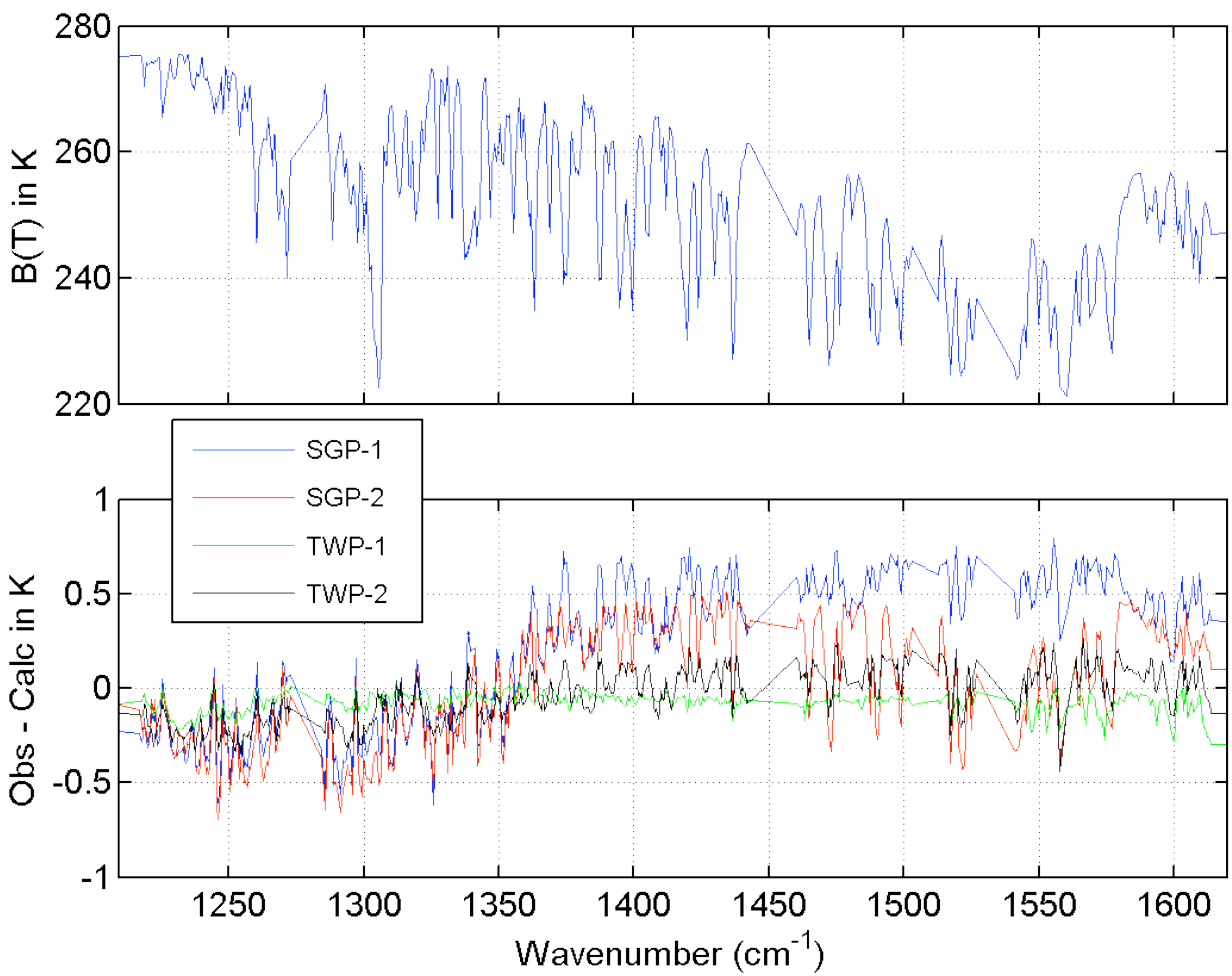
SGP Short Wave



SGP Long Wave

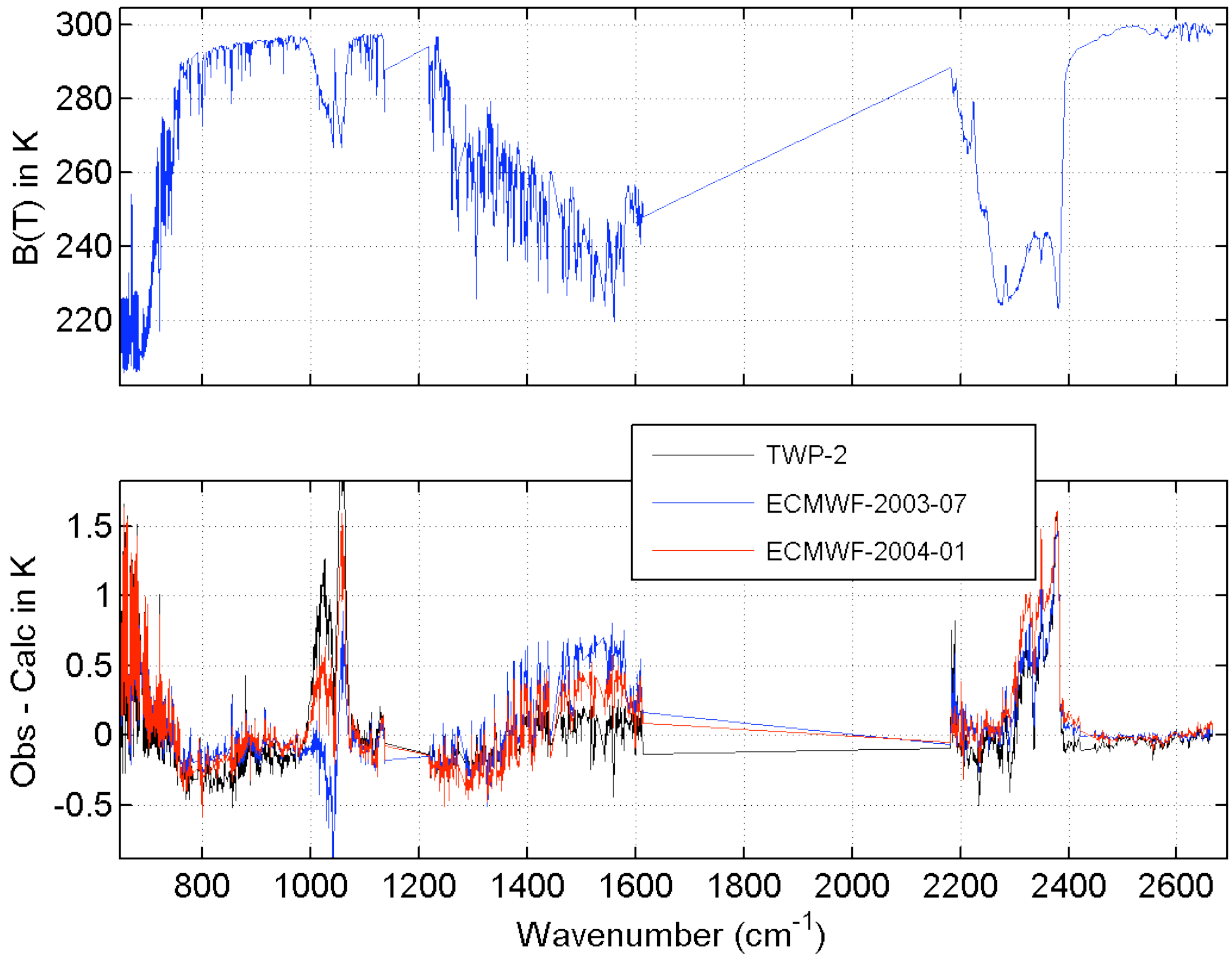


SGP and TWP Water Region

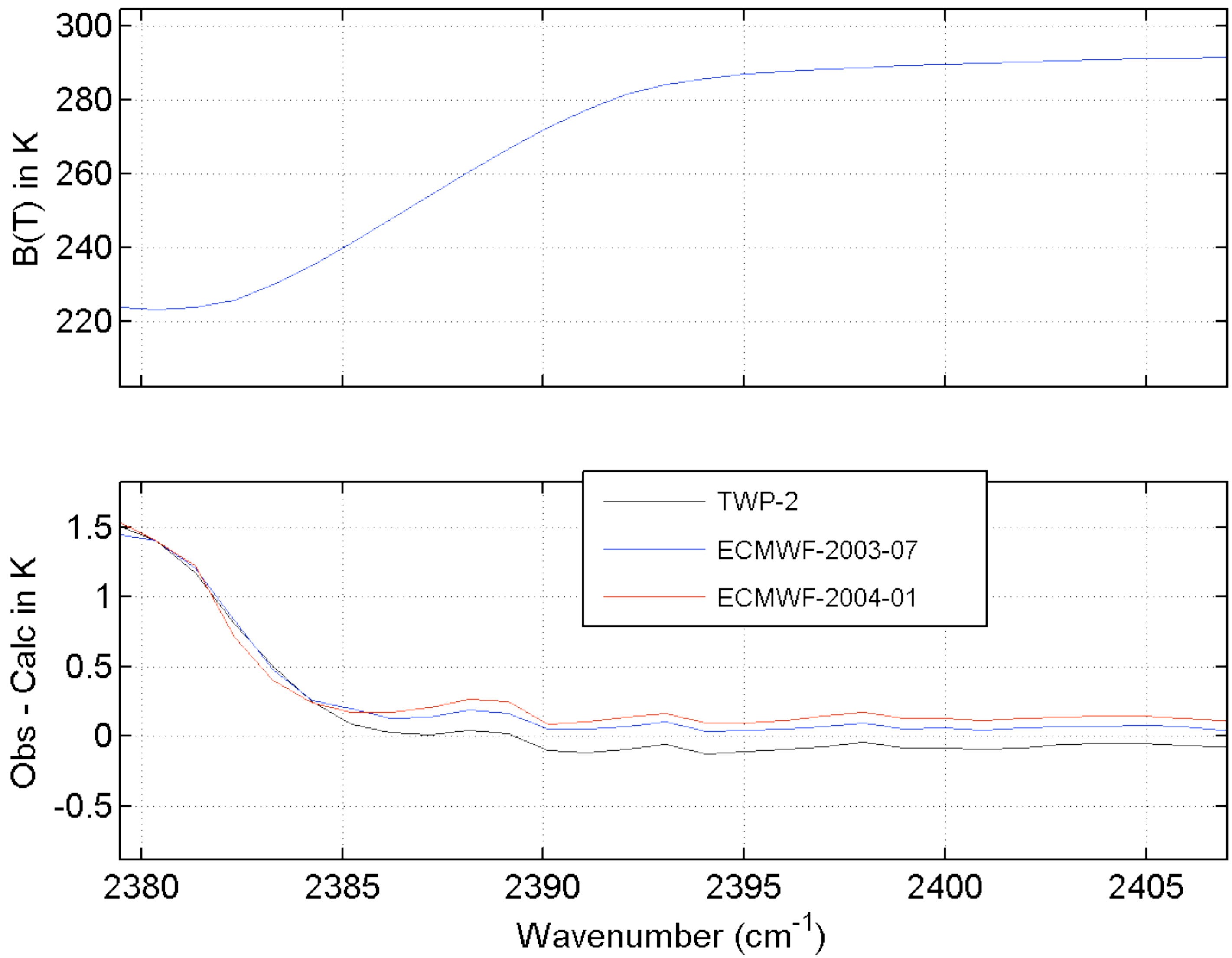


TWP versus ECMWF

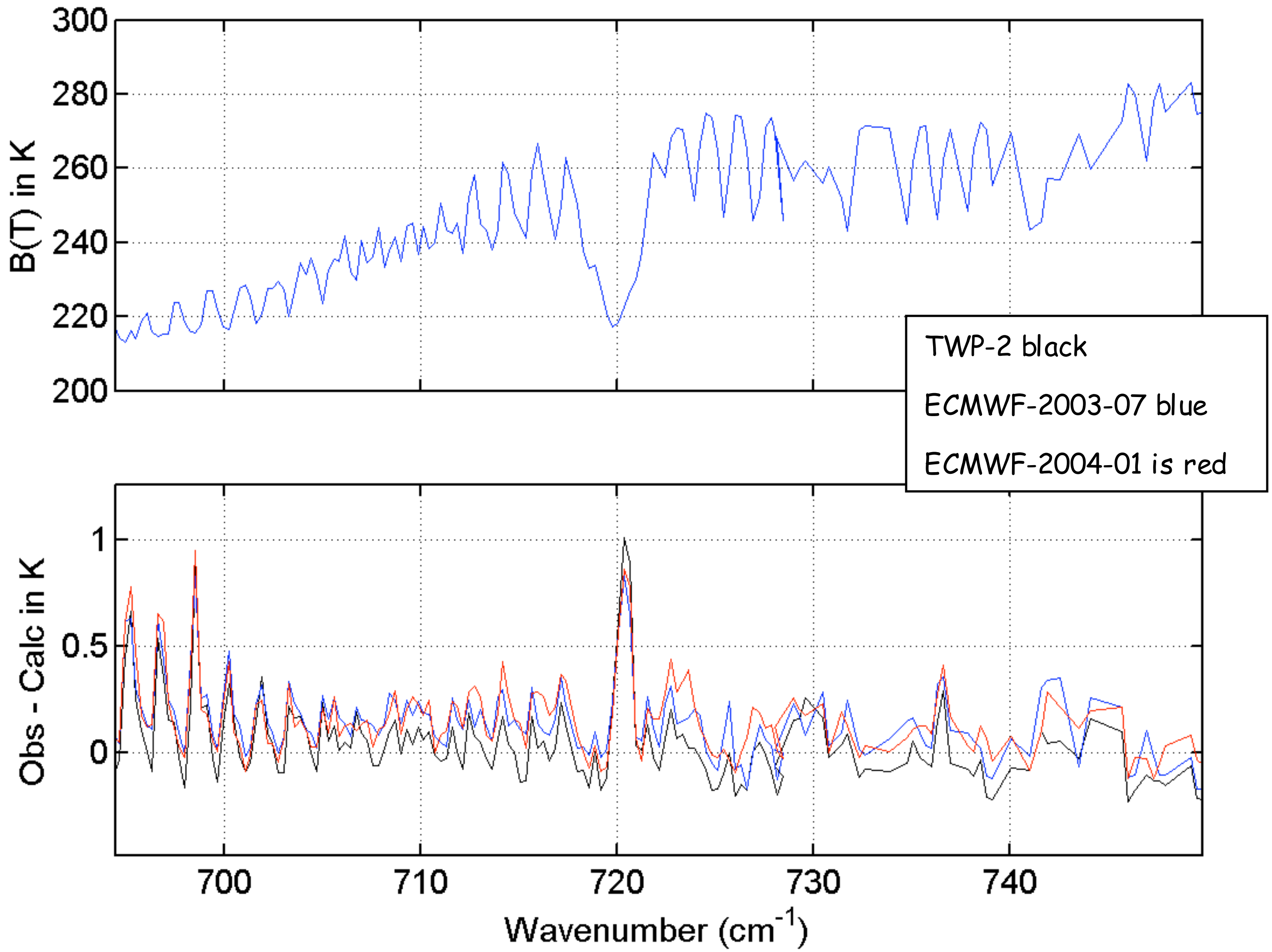
(ECMWF averaged over ~10-40 deg. Latitude)



TWP versus ECMWF



TWP versus ECMWF



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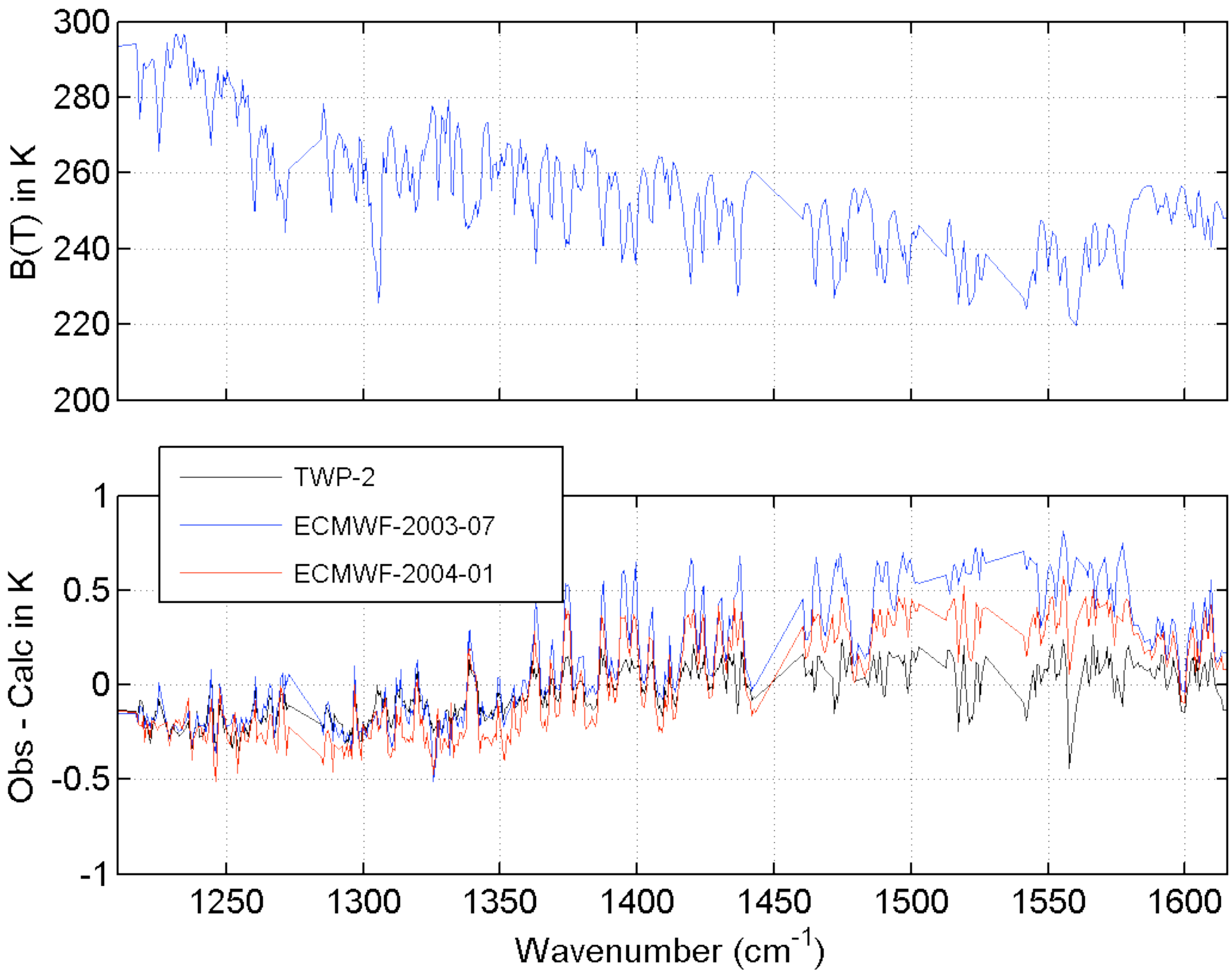
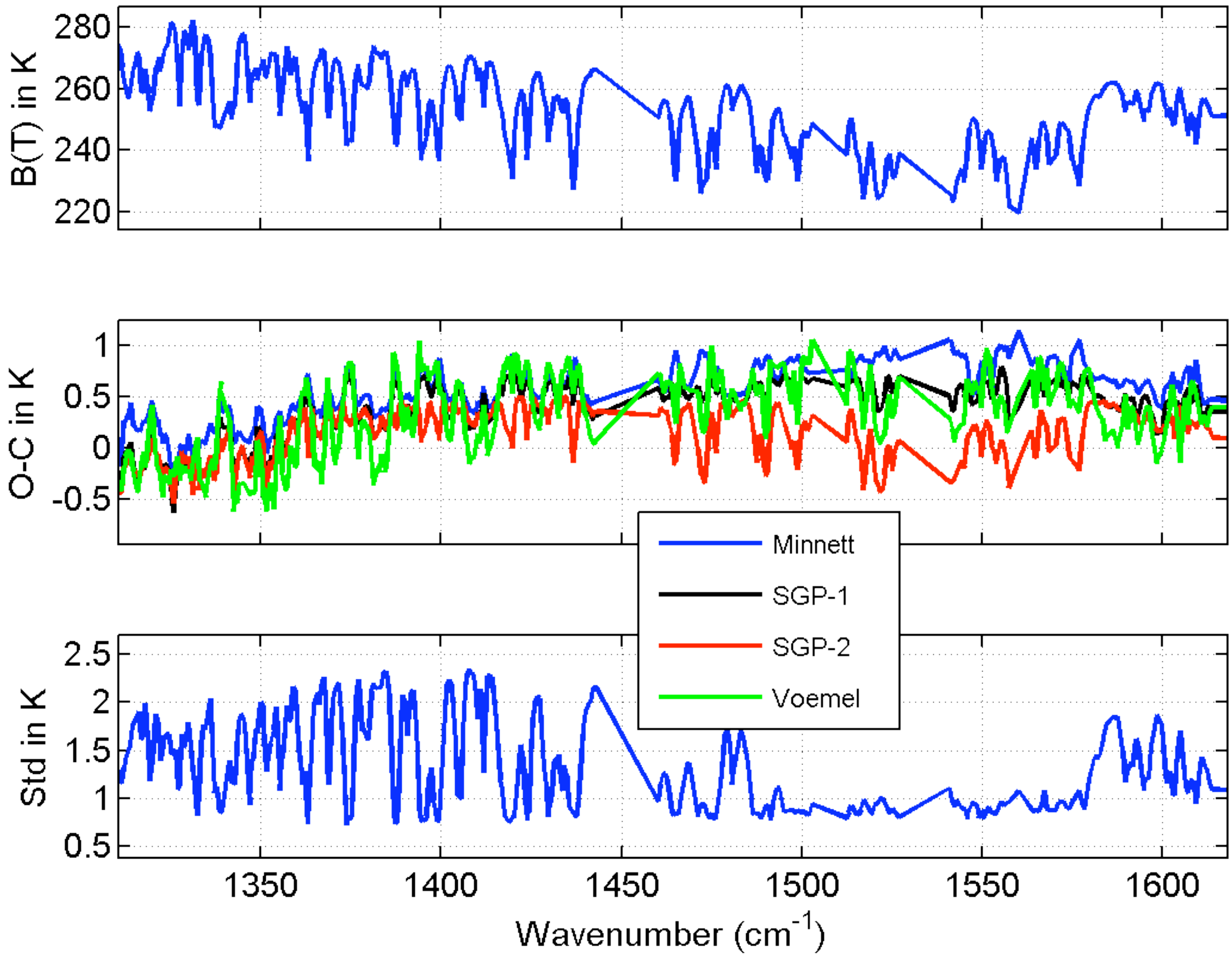
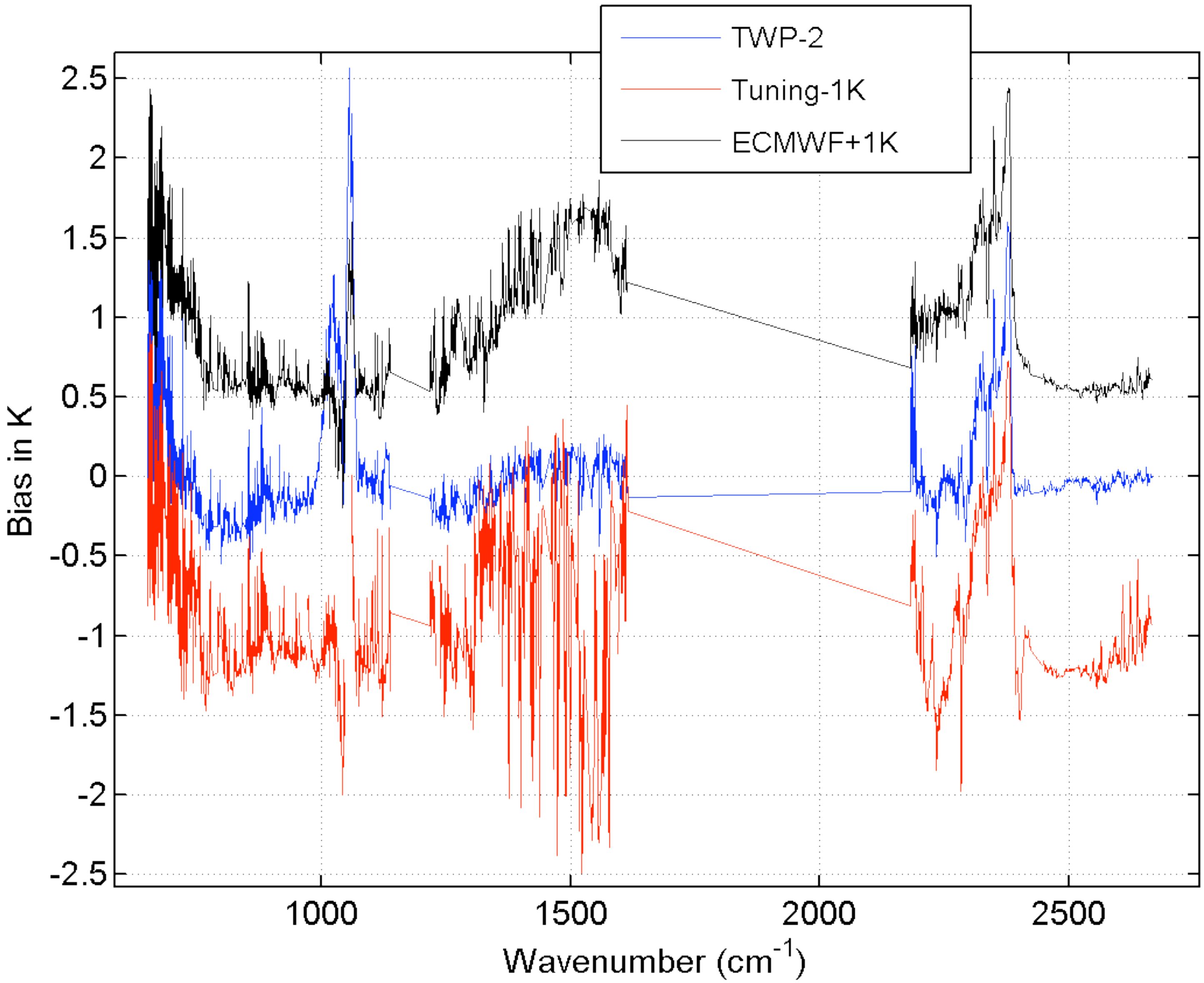


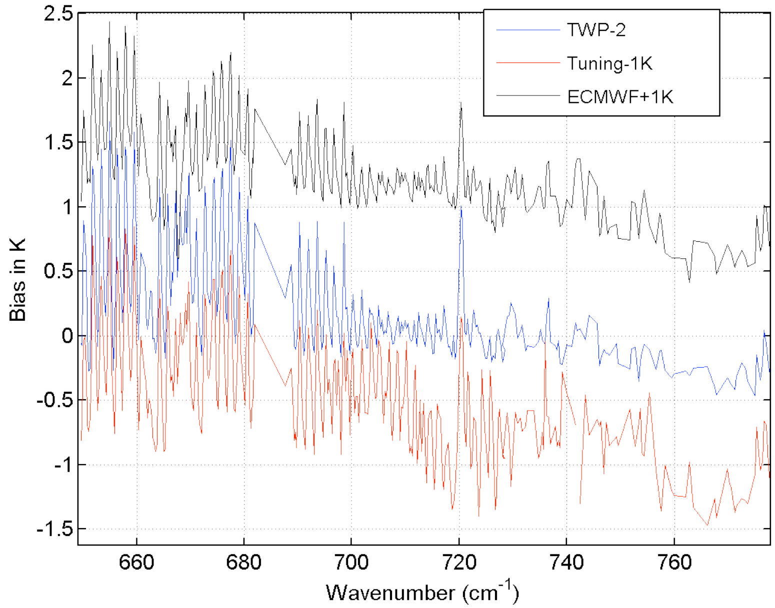
Minnett and Voemel

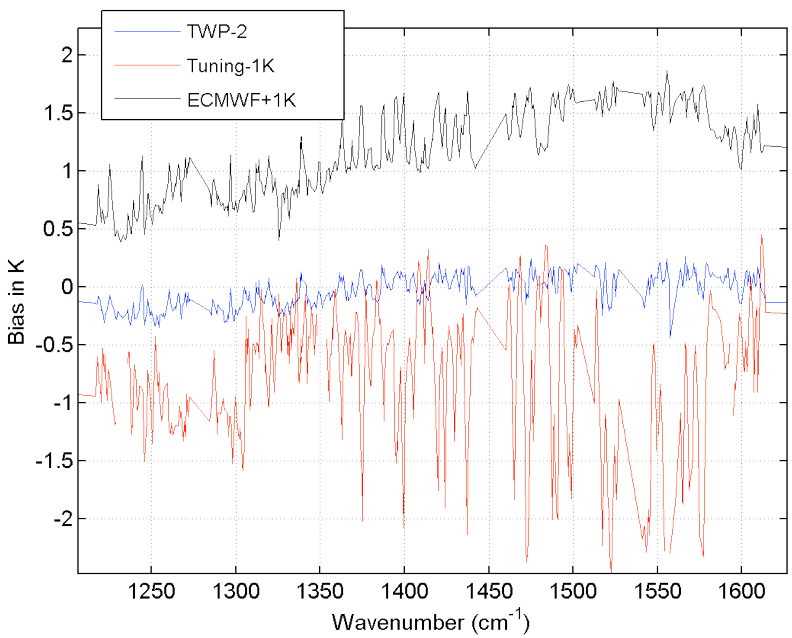


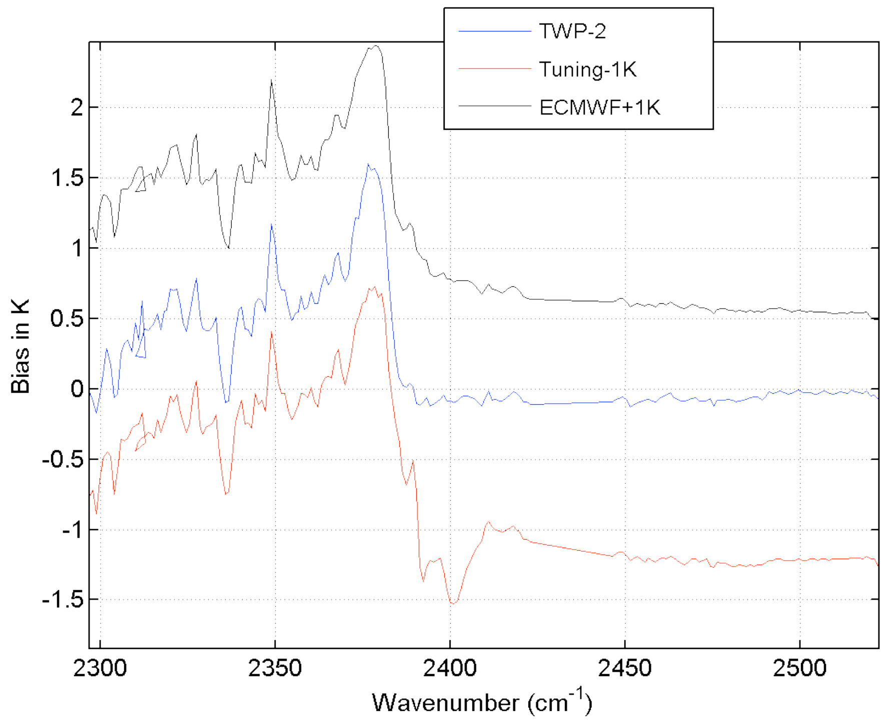
Validation Bias vs V3.x Tuning



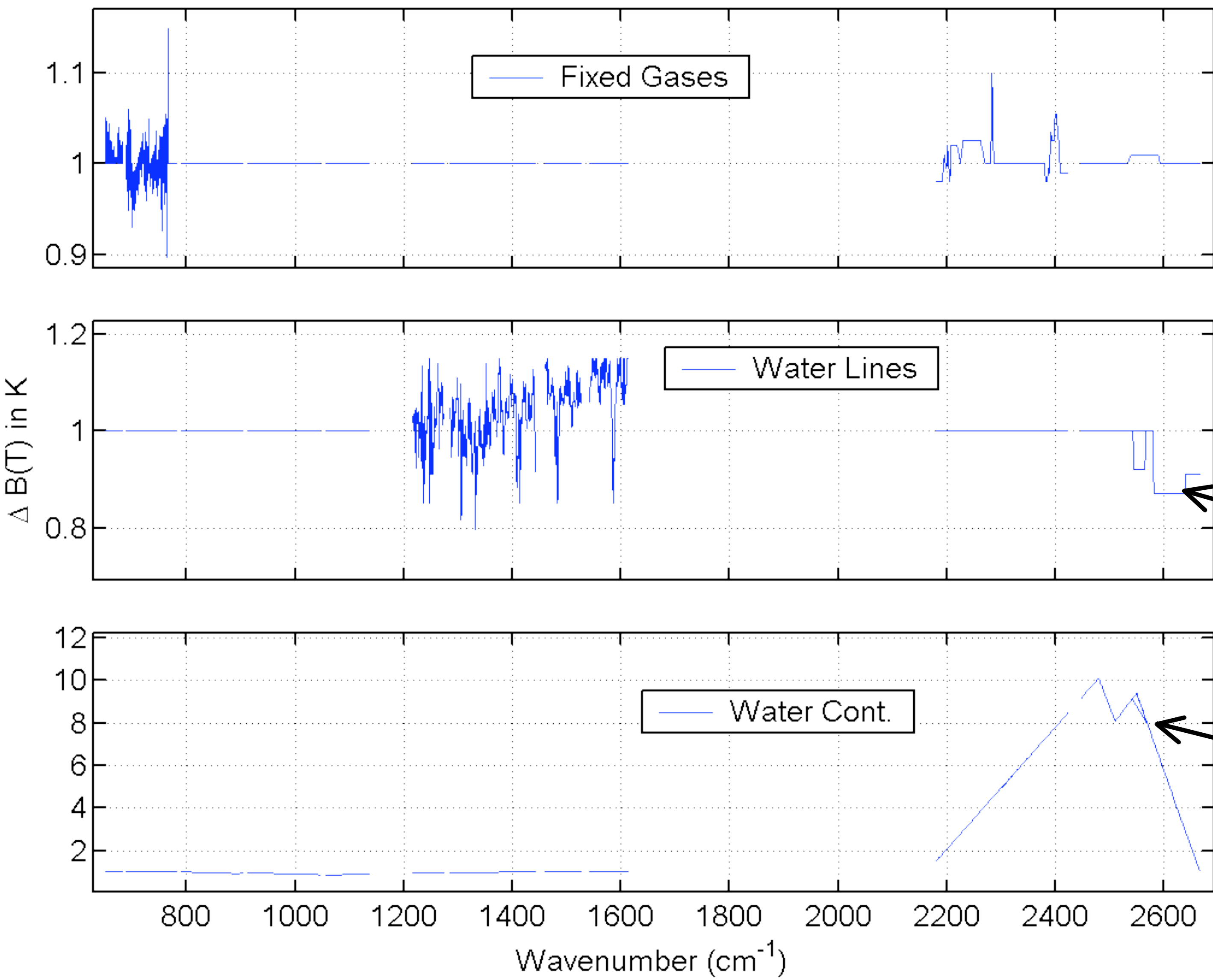
Validation Biases vs 3.x Tuning







Empirical Adjustments to RTA Transmittances

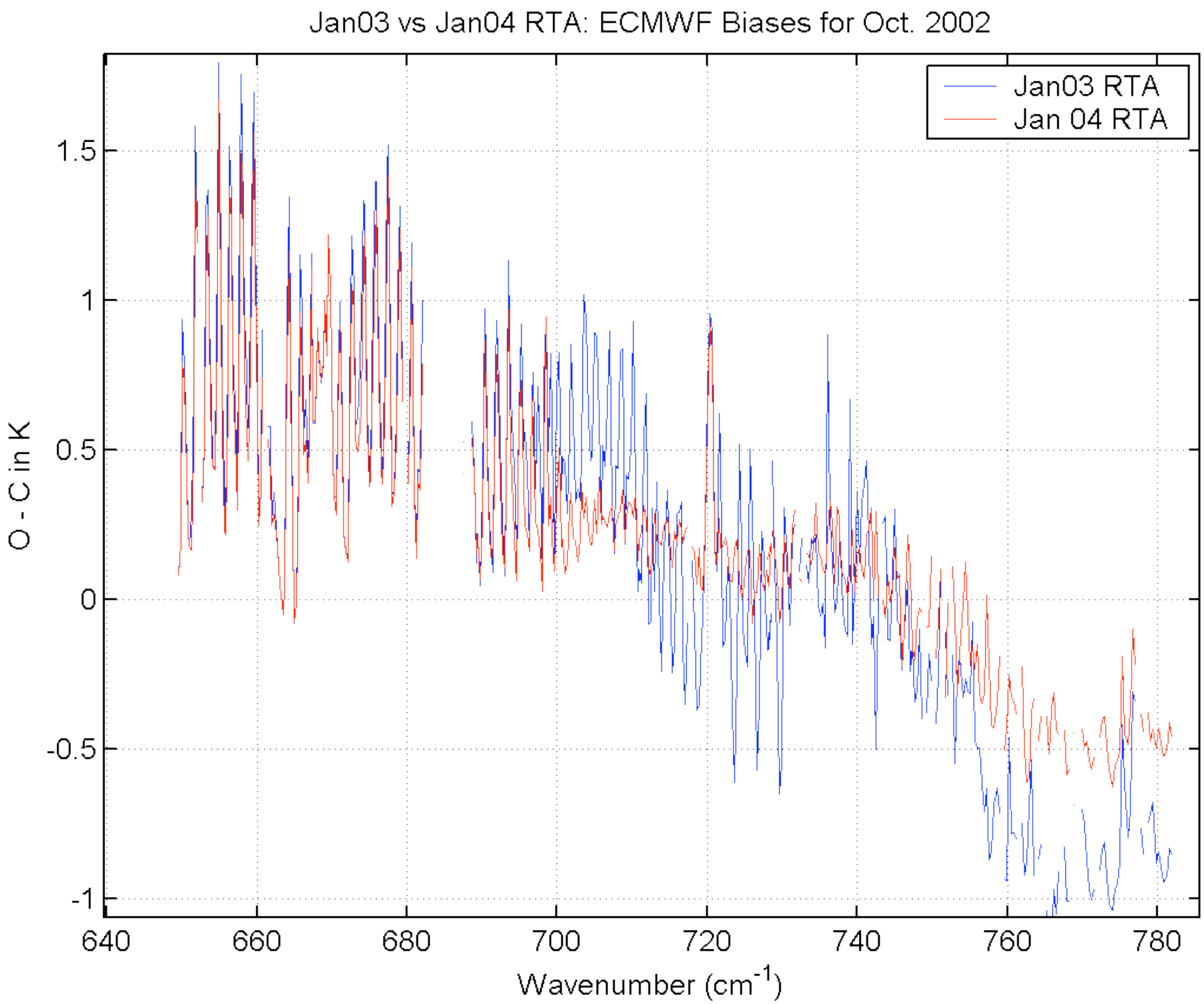


Adjustments suggested by TWP Obs not surprising given accuracy of fundamental spectroscopy

AERI ARM-SGP data analysis will improve these

Validated with AERI ARM-SGP

Improvements to ECMWF Bias from ARM-TWP Adjustments



Summary

- Freq Calibration:
  - Prototype S/W works (Matlab)
  - Fix only in L2 processing, what about L1b DAAC users?
- Fringes:
  - Can re-produce Nov 03 shifts
  - Assume we know absolute fringe positions (more modeling might help here)
- Scan Asymmetry
  - Static, but results are for clear only. Look at CC'd data.
- Non-LTE
  - Priority? We have plenty to do.
- Variable Gases
  - Use CMDL for CO_2 climatology? Need stratospheric climatology that doesn't exist
  - Add variable N_2O to RTA. Climatology for amount?
  - CH_4, handle with retrieval?
- RTA accuracy
  - With new large sonde data sets, more "tuning"? Add Miloshevich corrections and higher latitude datasets.
  - Is water band bias variability profile dependent?
  - Reflected thermal over land?